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Planning Guide For On-Site Greywater Disposal Systems For Recreational and Administrative Sites

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Planning Guide For On-Site Greywater Disposal Systems For Recreational and Administrative Sites

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PREFACE

The information and data contained in this publication are based on actual field experience, research, and literature. All the information and technology used in the selection, installation, and operation of a sewage treatment system is adaptable to the treatment and disposal of greywater.

Greywater has a different composition than combined waste from conventional systems. It is entirely free of black waste pollutants and is more esthetically acceptable for on-site treatment. Also, it is far more economical to process in terms of equipment and space required. The examples included are meant to acquaint Forest Service personnel with acceptable alternative methods of wastewater treatment and are not intended to provide definitive design information. The treatment devices/methods described must be sized to the parameters for each particular site. Finally, all plans and specifications must be approved by the appropriate agencies and adherence to codes is obligatory.

INTRODUCTION

This publication is intended to help the Recreation planner/designer. It lists the logical steps that must be explored before constructing or renovating a campground or administrative site. Also, it describes some of the newer methods of greywater/wastewater treatment that may be used at Forest Service sites.

The design staff must realize the importance of including maintenance personnel in the preliminary processes to ensure consideration is given to the installation, maintenance, and operation of the system once it is in place.

The two main reasons for examining new methods of greywater disposal are diminishing supplies of good water and rapidly escalating costs of treating both potable and/or wastewater. Secondary reasons for disposing of greywater separately include extending the life of the existing wastewater system and rehabilitating an existing wastewater system that has already failed because of overuse.

The primary goals of this planning guide are:

1. Assist the designer in obtaining safe and adequate on-site greywater treatment facilities
2. Minimize the exposure of the public to the disease transmission potential of domestic waste
3. Minimize the potential for contamination of drinking water supplies and hazards to recreational areas
4. Reduce the potential for surface and ground-water pollution.

PLANNING CONSIDERATIONS

One of the problems in wastewater treatment and disposal is the public's perception of wastewater. The public regards any water that has been through a sewer pipe or subjected to some contamination as though its molecular structure has been degraded. An effective way to deal with the public's misconception is to separate or eliminate toilet waste from the main volume of the wastewater. One area of water conservation that is often overlooked is the potential for reuse of water on-site. For example, in the typical administrative site, approximately 34 percent of the water consumed is used in flushing of toilets. The remaining 66 percent of the water can be recovered for reuse by on-site wastewater treatment and recycling systems and used for landscape irrigation and flushing of toilets and urinals. Whether disposed of to the soil or to the surface, wastewater will need to be treated according to its eventual reuse, including possibly for drinking.

It will be necessary, with some of the more visible methods of wastewater treatment, to include the public along with Federal, State, local agencies, and various environmental groups in the conceptual design phase. Be advised that it is **extremely** important to include the public in the planning group as mentioned above, since they may have some preconceived notions that are difficult to unseat.

Many Forest Service wastewater problems require innovative, creative, and cooperative solutions. A positive working environment is needed with water agencies, legislators, regulators, environmentalists, and the public. Together, new issues can be resolved by using new technologies and innovative approaches to water resources management.

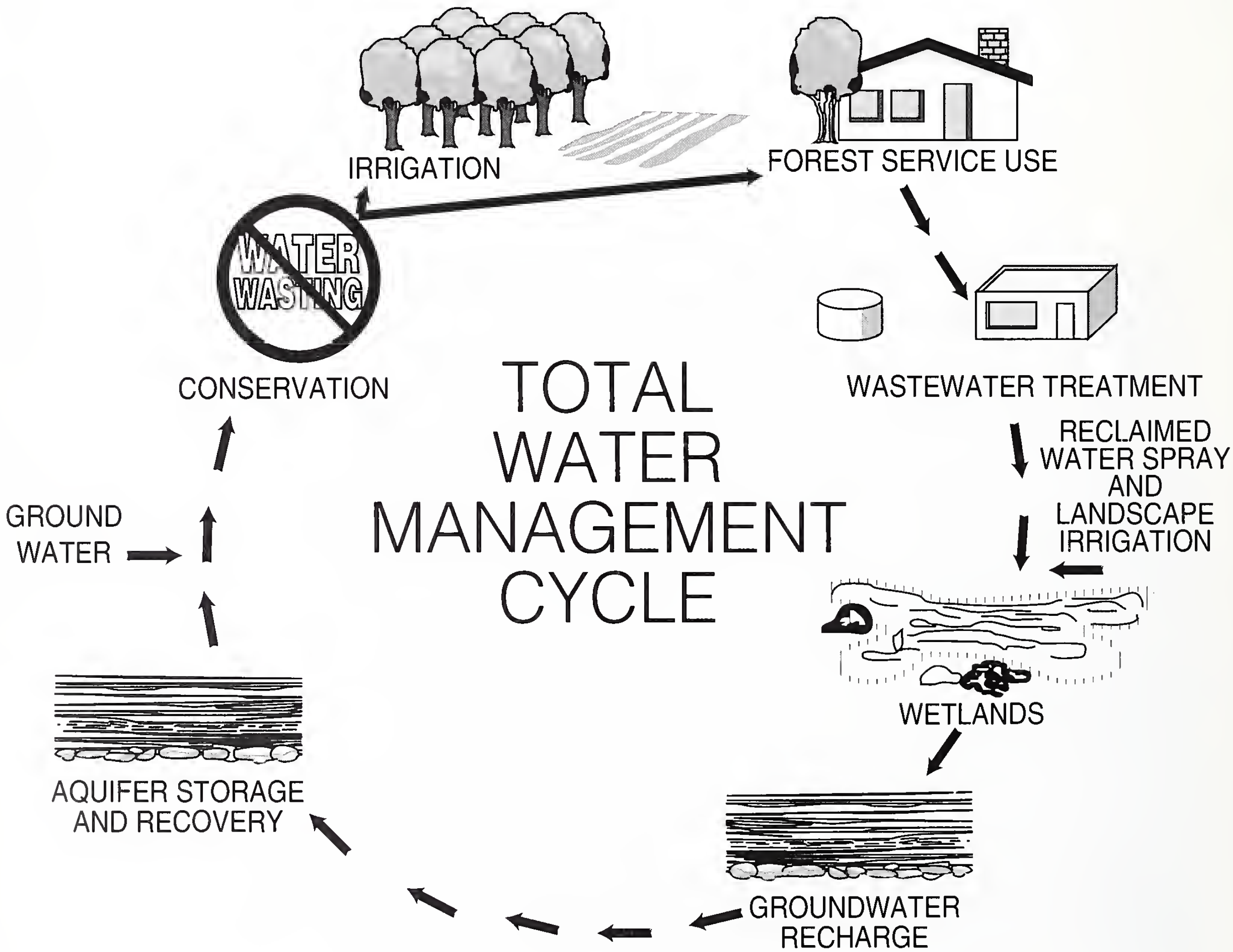


Figure 1.—Total water management cycle.

PLANNING STEPS FOR A GREYWATER DISPOSAL SYSTEM

Site Evaluation

Determine if the design can be accomplished at the proposed site. Look at the topography to determine drainage and severe slope areas. Is there any surface water? What are the soil characteristics? Where is the ground water? Who else is affected by a subsurface disposal field? What watersheds would be affected? What potable water sources are downstream? How far?

Determine Quantity of Greywater to be Treated or Disposed Of

Look at the design to determine the number of sites, the population-at-one-time (PAOT), and the number and type of fixtures to be installed. Check with the Forest and/or District to see if plans for expansion will be forthcoming. Plan for additional people anyway! Be sure to insist on the use of water conserving types of low-flow toilets, faucet flow restrictors, low-flow hose bibs, and low-flow shower heads. Use the Uniform Plumbing Code and Forest Service Handbook (FSH 7409.11, Chapter 50) to size the system.

Determine the Characteristics of the Greywater

Campground visitors will generally use throw-away plates and cutlery so greywater generation from washing plates, spoons, and forks will be minimal. However, cooking utensils will be washed. Also, visitors are likely to pour cooking oil and grease (animal fat) into the greywater collection system, once installed, making the concentration of grease and oil comparable with greywater from a restaurant kitchen sink. Because of low usage of water at the campsites, the concentration of grease in the campground greywater is expected to be even higher than restaurant greywater.

Table 1 gives the average characteristics of restaurant greywater for estimating purposes. The true character of pollutant concentrations can only be determined through laboratory testing. (Reference 1.)

Review Applicable Guidelines for Disposal of Greywater

Most states require that greywater and blackwater (sewage) be handled in the same fashion as far as treatment and disposal are concerned. (Some late revisions to this policy are discussed later in this publication.) Federal, State, and local codes and regulations regarding the collection, storage, treatment, and disposal of greywater must also be followed. Some states now require that greywater treatment system designers be either a licensed sanitary engineer or have passed a state certification test.

Preliminary Planning Considerations

How much land area is available for greywater treatment? Are climatic conditions acceptable for the type of system selected? Is there power available? Is there a sufficient quantity of water available at a high enough pressure? Is the campground or facility existing or only in the planning stages? Does the collection system need to be replaced?

What ecological considerations must be addressed? Of the greywater treatment alternatives addressed later in this publication, which one would provide the best choice for a particular site, at the lowest cost (both construction and maintenance/operation). All facilities should be designed for use by people with disabilities.

Table 1.—*Average concentrations (mg/l) of pollutants.*

Pollutant	Kitchen
Chemical Oxygen Demand (COD)	1400
Five-Day Biochemical Oxygen Demand (BOD_3)	700
Nitrogen Compounds (NO_3-N,NH_3-N)	5
Inorganic Phosphate (PO_4)	10
Suspended Solids	500
Grease	750

Select a Suitable Option

Select a greywater system that:

1. Is simple and dependable
2. Minimizes the need for special skills to operate
3. Is reasonable in cost to construct and maintain
4. Complies with rules and regulations of Federal, State, and local agencies
5. And is environmentally benign.

STORAGE OPTION

Holding Tank

In recreation sites the tank should be sized in such a way that its pump out can be synchronized with that of the toilet vaults thereby minimizing operating cost. The tanks are made of concrete, polyethylene, or fiberglass. When using the plastic tanks be sure to locate the water table since these tanks can float if they are not secured. By using a gravity collection system a single holding tank can be used to serve several camping units. A separate grease interceptor (grease trap) is recommended. A 3785.3 liter (1000 gallon) concrete tank costs about $700; the same size polyethylene tank costs about $875, and a comparable fiberglass tank costs about $1400.

The following section presents information on the components of an on-site system that provides "treatment" of the greywater, as opposed to its "disposal" (see Disposal Options for treated wastewater).

The purpose of a treatment component is to transform the in-flowing raw wastewater into an effluent suited to the disposal component, thereby allowing the wastewater to be disposed of in conformance with public health and environmental regulations. For example, in a subsurface soil absorption system, the pretreatment unit (e.g., septic tank) should remove nearly all settleable solids and floatable grease and scum so that a reasonably clear liquid is discharged into the soil absorption field. This allows the field to operate more efficiently. Likewise, for a surface discharge system, the treatment unit should produce an effluent that meets applicable surface discharge requirements. (Reference 2.)

TREATMENT OPTIONS

Treatment options included in this discussion are:

1. Greywater disposal sumps
2. Septic tanks
3. Sand filters
4. Aerobic treatment units
5. Natural or constructed wetlands
6. On-site filter

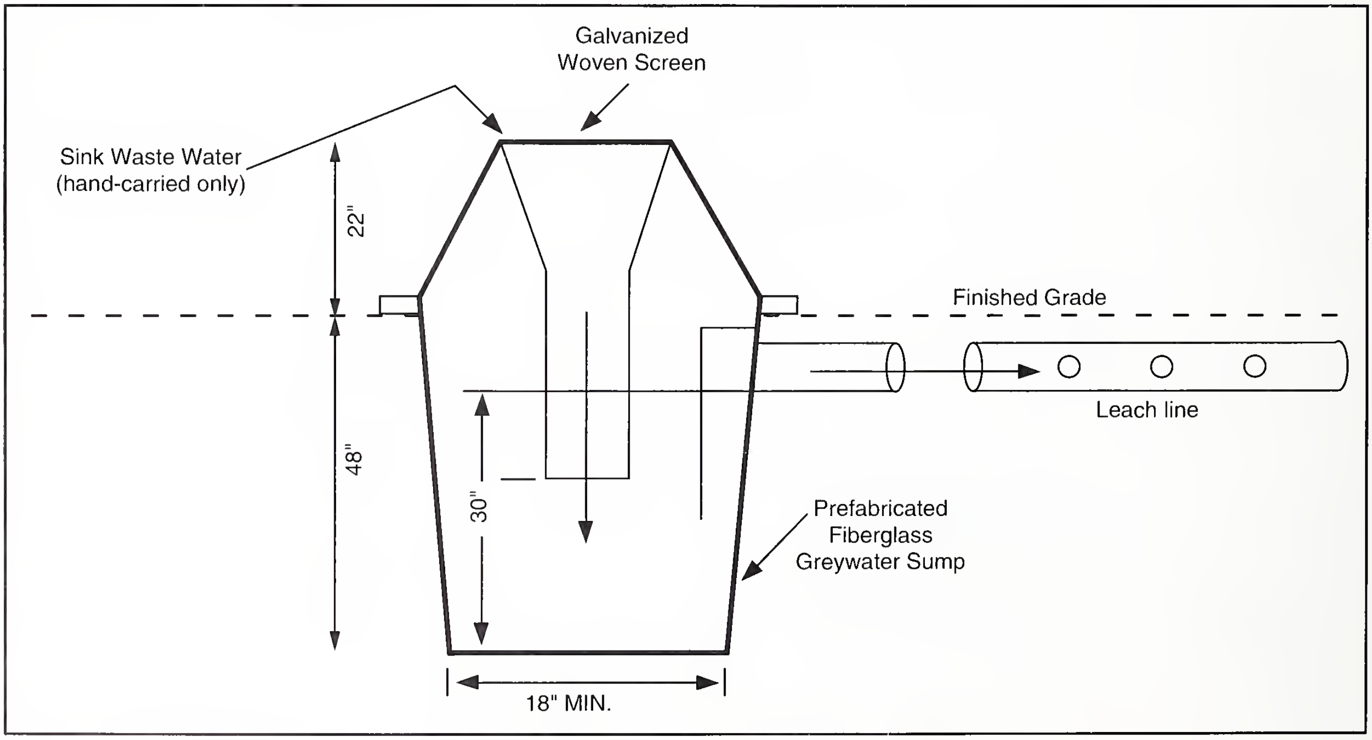


Figure 2.—*Greywater sump (mini septic tank).*

7. RUCK System

8. Land Treatment

9. “Cycle-Let” System

10. Solar Aquatic System

Greywater Disposal Sumps

If a soil absorption system is feasible, a greywater sump (figure 2) may be an option since it does not require an elaborate leach field. Depending on the runoff volume and the proximity of the camping units/ spurs, the system designer will determine the number of sumps required and their relative locations. A 265 liter (70 gallon) unit is available for under $500 FOB Portland, OR. The system has its limitations. The daily flow of greywater should not exceed 37.9 liters (10 gallons) per unit. It is reported that the sump is not very effective against oil and grease buildup. The sump generally is used to catch the washwater from frying pans, etc., and the percentage of fat and grease is very high. (Reference 3.)

Septic Tanks

Septic systems (figure 3) are very effective when climatic and soil conditions are favorable. A septic tank is an anaerobic system; it separates settleable and floatable materials from wastewater, and stores and digests these materials in the same tank. Minimum tank volume requirements are spelled out in State codes or local regulations. It is advisable to have more storage space and liquid retention time than the minimum required by the codes. The septic tank effluent can be transported for secondary treatment and/or disposal to a subsurface absorption field, to a mound system, to an Evapotranspiration Bed or a Evapotranspiration/ Absorption Bed, to an Evaporation Lagoon or an Evaporation/Infiltration Lagoon, to a natural or constructed wetland, or to a filter system. For campground use, a separate grease interceptor (grease trap) is strongly recommended.

Intermittent Sand Filtration

Intermittent sand filtration may be defined as an intermittent application of wastewater to a bed of granular materials 61 to 91 cm (24 to 36 inches) deep and underlain by graded gravel and collecting tile. Wastewater is applied intermittently to the surface of the bed through distribution pipes or troughs. Uniform distribution is normally obtained by dosing to flood the entire surface of the bed. It is one of the oldest methods of wastewater treatment known. If properly designed, constructed, and operated, it will produce effluents of very high quality. Intermittent sand filtration is well suited to on-site wastewater treatment and disposal. The process is highly efficient, yet requires a minimum of operation and maintenance.

The process is applicable to campgrounds and administrative sites but its size is limited by land availability. The wastewater applied to the intermittent filters should be pretreated at least by sedimentation;

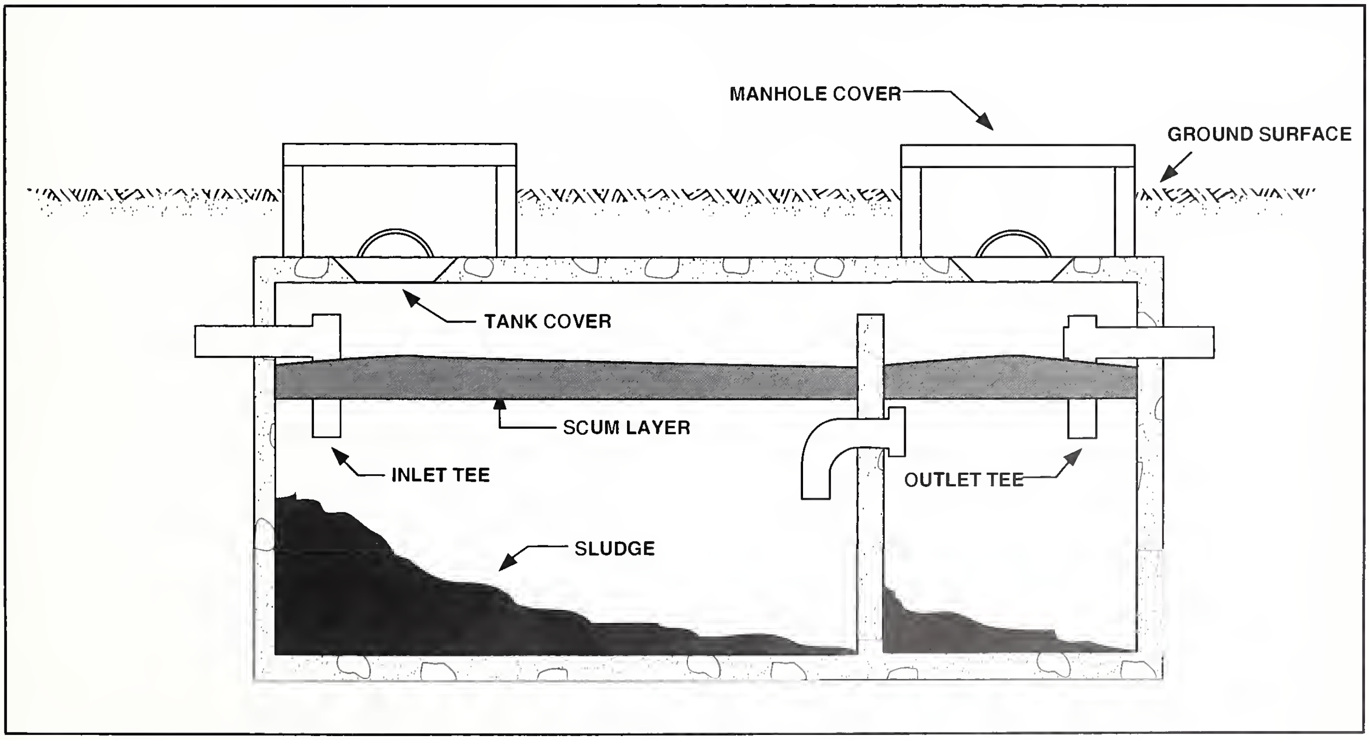


Figure 3.—*Septic tank.*

septic tanks should be required as a minimum. Additional pretreatment by aerobic biological processes normally results in higher acceptable rates of wastewater application and longer filter runs. There is some evidence that higher loading rates and longer filter runs can be achieved with pretreated greywater.

Intermittent sand filters may be built on the surface of the ground or buried within the ground. (Figure 4a.) Free access intermittent sand filters are usually at ground level with removable covers for maintenance. (Figure 4b.) Recirculating filters incorporate a recirculation chamber (dosing chamber) to recycle filter effluent. (Figure 4c.)

Aerobic Treatment Units

Facultative Lagoons (Stabilization Ponds)

Facultative lagoons or ponds (figure 5) are the most frequently used form of municipal wastewater treatment in the United States with more than 5000 systems currently in operation. These lagoons are usually 1.2 to 1.8m (4 to 6 feet) in operating depth and are not mechanically mixed or aerated. The layer of water near the surface is aerobic due to atmospheric reaeration and algal respiration. The layer at the bottom of the lagoon is anaerobic and includes sludge deposits. The intermediate layer (facultative zone) ranges from aerobic near the top to anaerobic at the

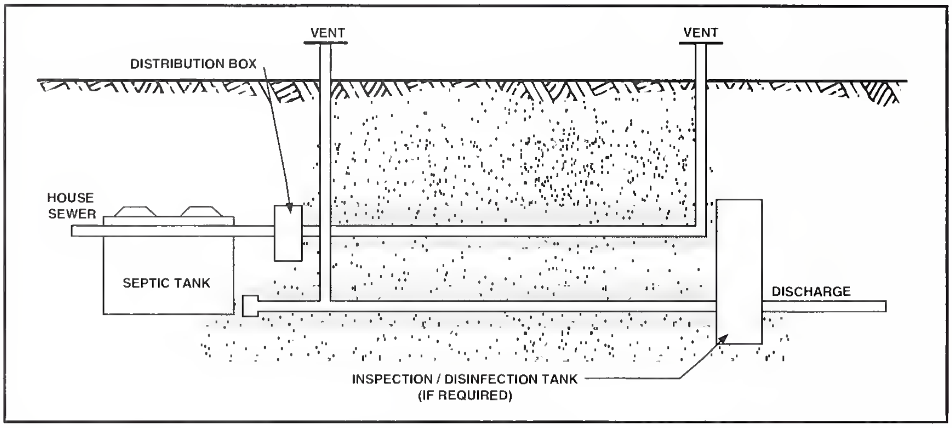


Figure 4a.—Buried (single-pass) sand filter.

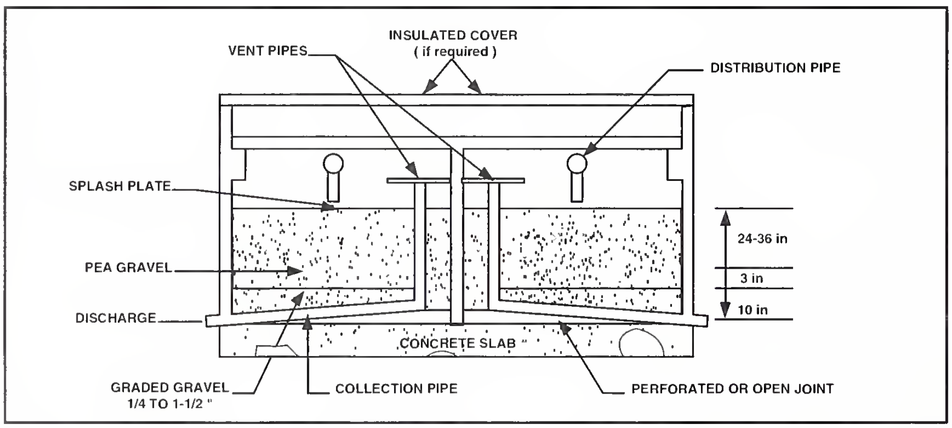
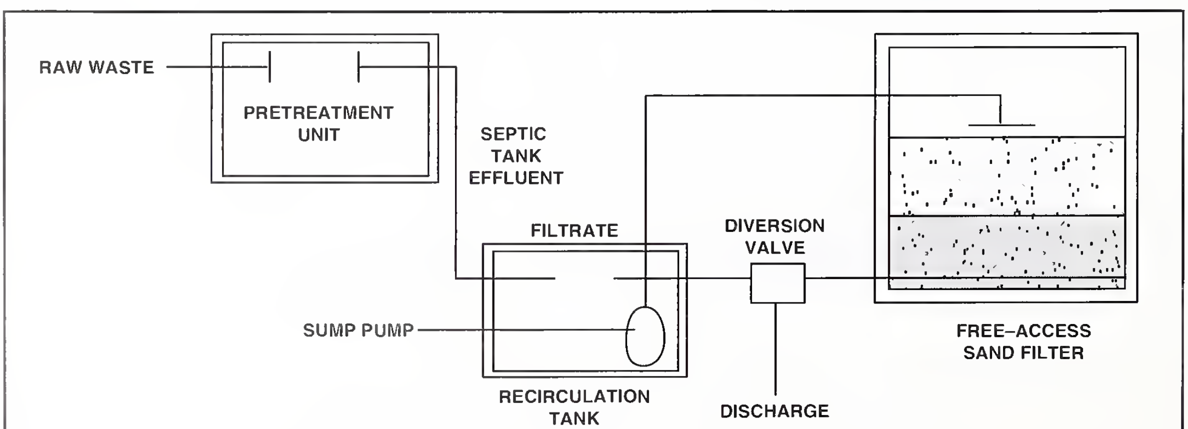


Figure 4b.—Open (intermittent) sand filter.

Figure 4c.—Basic recirculating sand filter.



bottom. The layers may be indistinct or be clearly defined due to temperature-related water-density variations. Disruptions can occur in the spring and fall of each year when the surface layer of melted ice may have a higher density than lower layers. This higher density water induces vertical movement, mixing the pond contents and producing objectionable odors due to the release of anaerobically formed gases. (Reference 4.)

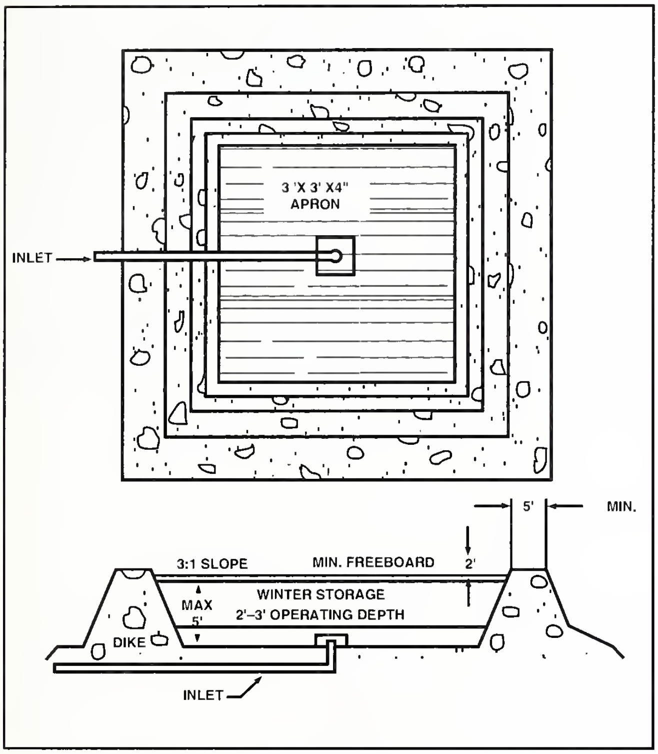


Figure 5.—*Typical facultative lagoon for small installations.*

Aerated Lagoons

Aerated lagoons are smaller and deeper than facultative lagoons and are designed for biological treatment of wastewater on a continuous basis. In contrast to stabilization ponds, which obtain oxygen from photosynthesis and surface reaeration, aerated lagoons typically employ devices that supply supplemental oxygen to the system. The aeration devices may be mechanical (e.g., surface aerator) or diffused air systems using submerged or overhead pipes. Surface aerators are divided into two types: caged aerators and the more common turbine and vertical shaft aerators. Diffused air systems used in shallower lagoons typically consist of plastic pipes supported near the bottom of the lagoon cells with regularly spaced sparger holes drilled in the tops of the pipes. Overhead air headers and finer bubble systems have recently been applied. Because shallower aerated lagoons are normally designed to achieve partial mixing only, aerobic/anaerobic stratification may occur. Large fractions of incoming solids and the biological solids produced from waste conversion can settle to the bottom of the lagoon cells. (See figure 6 and Reference 4.)

Natural or Constructed Wetlands and Aquatic Treatment Systems

Wetlands are lands where the water surface is near the ground surface for enough of the year to maintain saturated soil conditions and promote related vegetation. Constructed wetlands are similar systems specifically designed for wastewater treatment. Most natural wetlands are considered receiving waters and are subject to applicable laws and regulations regarding discharge. Influent to currently operating constructed wetland systems ranges from septic tanks to secondary effluents.

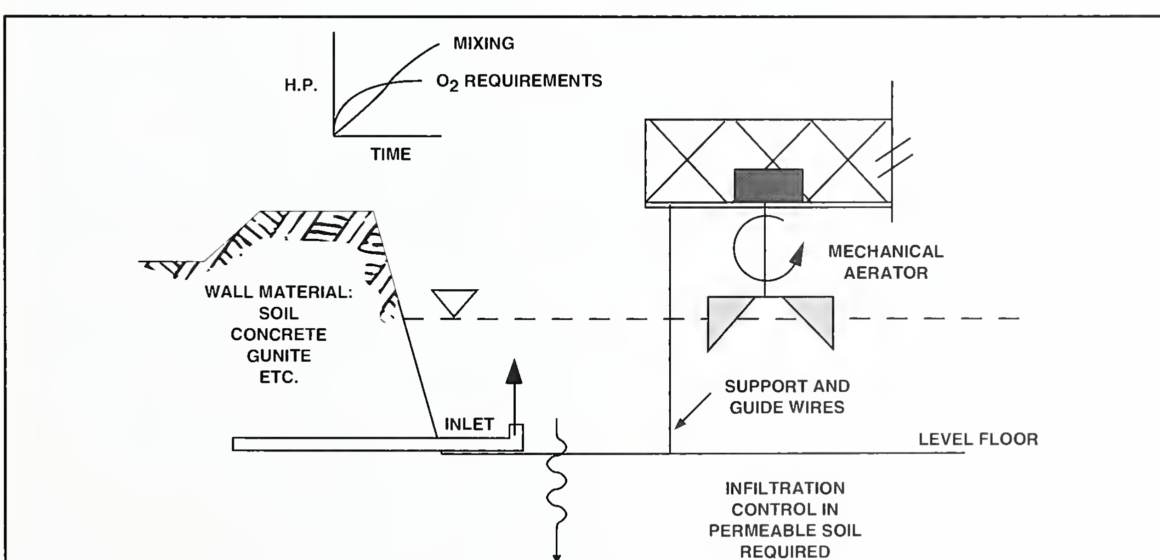


Figure 6.—*Aerobic lagoon with external mechanical energy.*

The two different types of constructed wetlands are characterized by the flow path of the water through the system. The first, called a free-water surface (FWS) wetland, includes appropriate emergent aquatic vegetation in a relatively shallow bed or channel. The surface of the water in this system is exposed to the atmosphere as it flows through the area.

The second type of constructed wetland, called a subsurface flow (SFS) wetland, (figure 7) includes a foot or more of permeable media (rock, gravel, or course sand) that supports the root system of the emergent vegetation. The water in the bed or channel in such a system flows below the surface of the media.

Both types of constructed wetland typically include a barrier to prevent ground-water contamination beneath the bed or channel. Barrier materials range from compacted clay to membrane liners. A variety of wastewater application methods have been used with constructed wetlands. Different outlet structures and methods have been developed to control the depth of water in the system. (Reference 4.)

The performance of any constructed wetland system is dependent upon the system hydrology. Other factors, such as precipitation, infiltration, evapotranspiration, hydraulic loading rate and water depth can affect the removal of organics, nutrients, and trace elements, by altering the detention time but also by either concentrating or diluting the wastewater. Prepare a hydrologic budget to properly design a constructed wetland treatment system. Changes in the detention time or water volume can significantly affect the treatment performance.

Historical climatic records can be used to estimate precipitation and evapotranspiration. In the western states, both riparian and appropriative water rights may be affected by adopting a constructed wetlands system. The effects can include site drainage (quality and quantity), change of location for surface water discharge and reduction of the quantity of a surface water discharge. If an existing surface discharge is to be affected, replacement of downstream water rights may be necessary.

On Site Filter and Disinfection

The Texas Natural Resources Conservation Commission has proposed additions to the Texas Water Code that will allow on-site treatment of household greywater. The greywater must be separated from the blackwater system and run through a diatomaceous earth or sand filter and some kind of disinfection (e.g., chlorination, ozonization, or ultraviolet radiation). The code will require submittal of a technical report, a site drawing, soil evaluation, landscape plan, installation typicals, maintenance and periodic testing by a registered installer. The treated greywater can be used for spray irrigation on the owners' property. (Reference 7.)

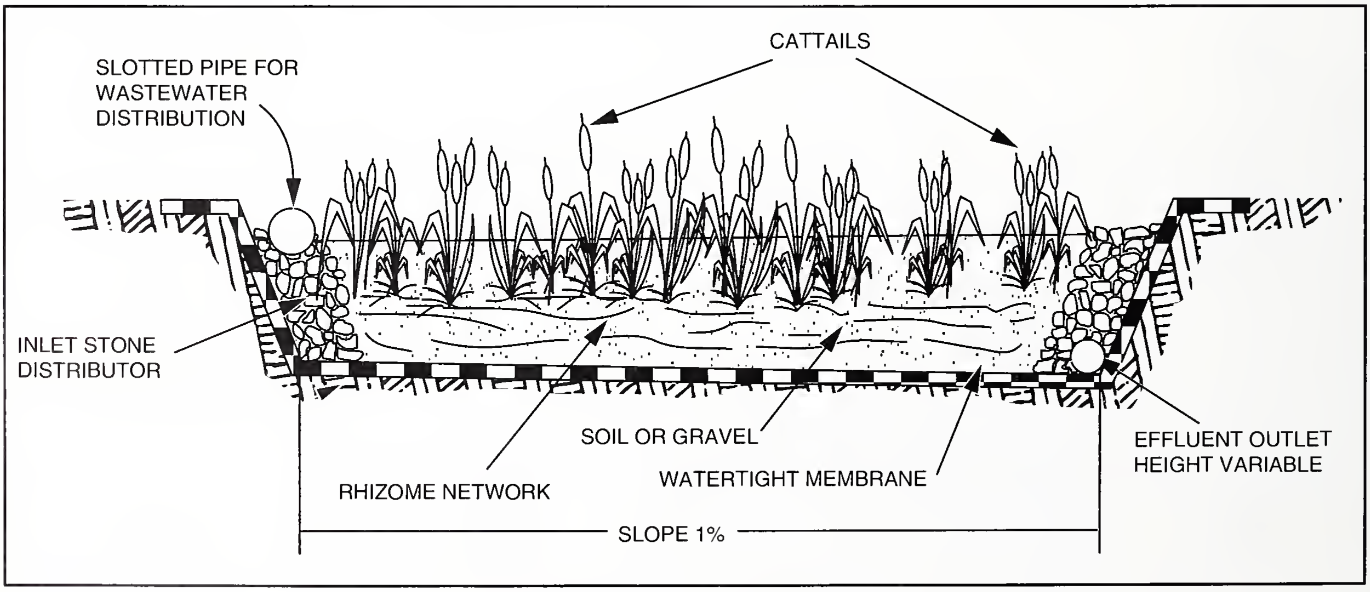


Figure 7.—*Typical cross section of SFS system.*

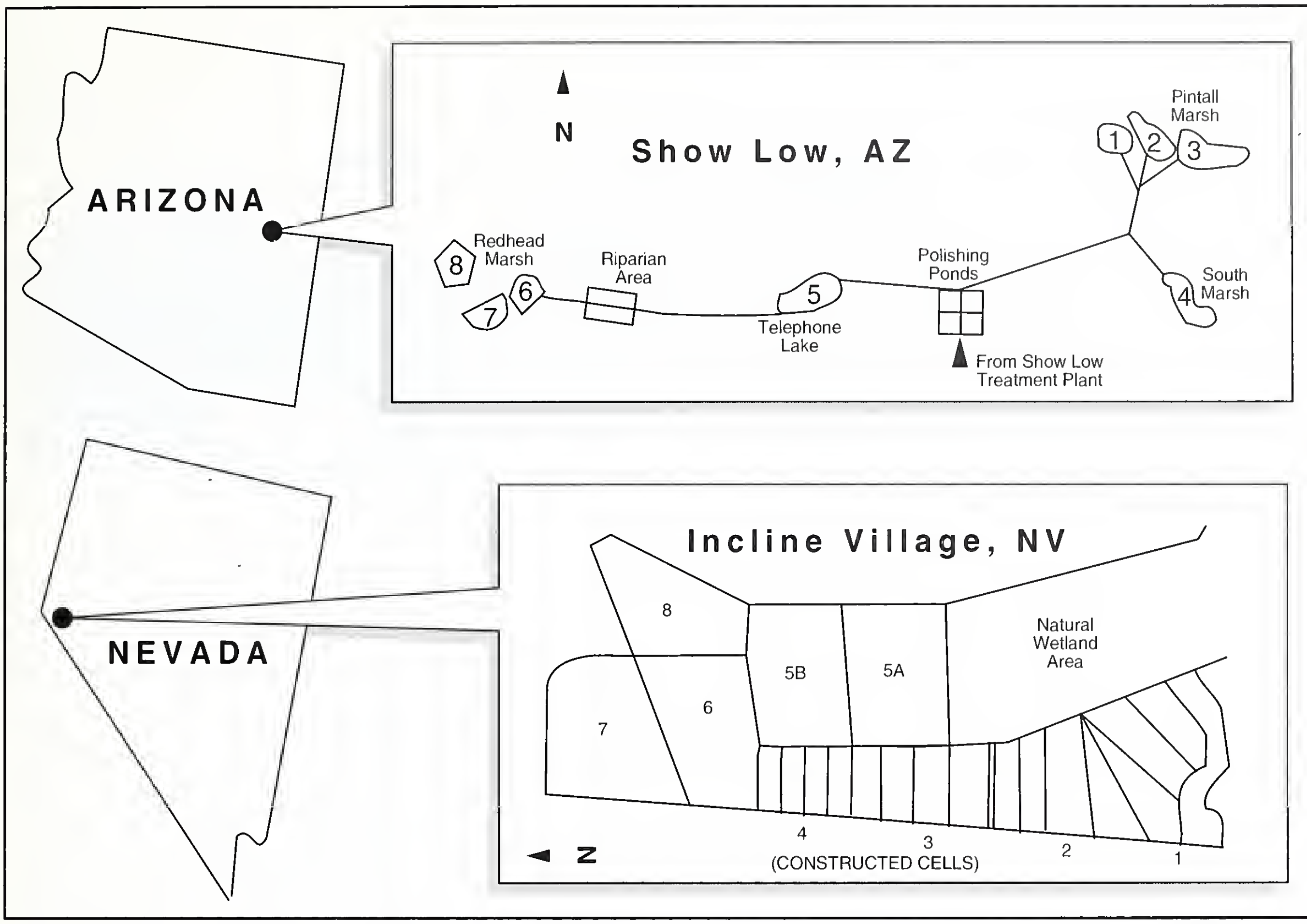


Figure 8.—*Location and layout of constructed wetland sites.*

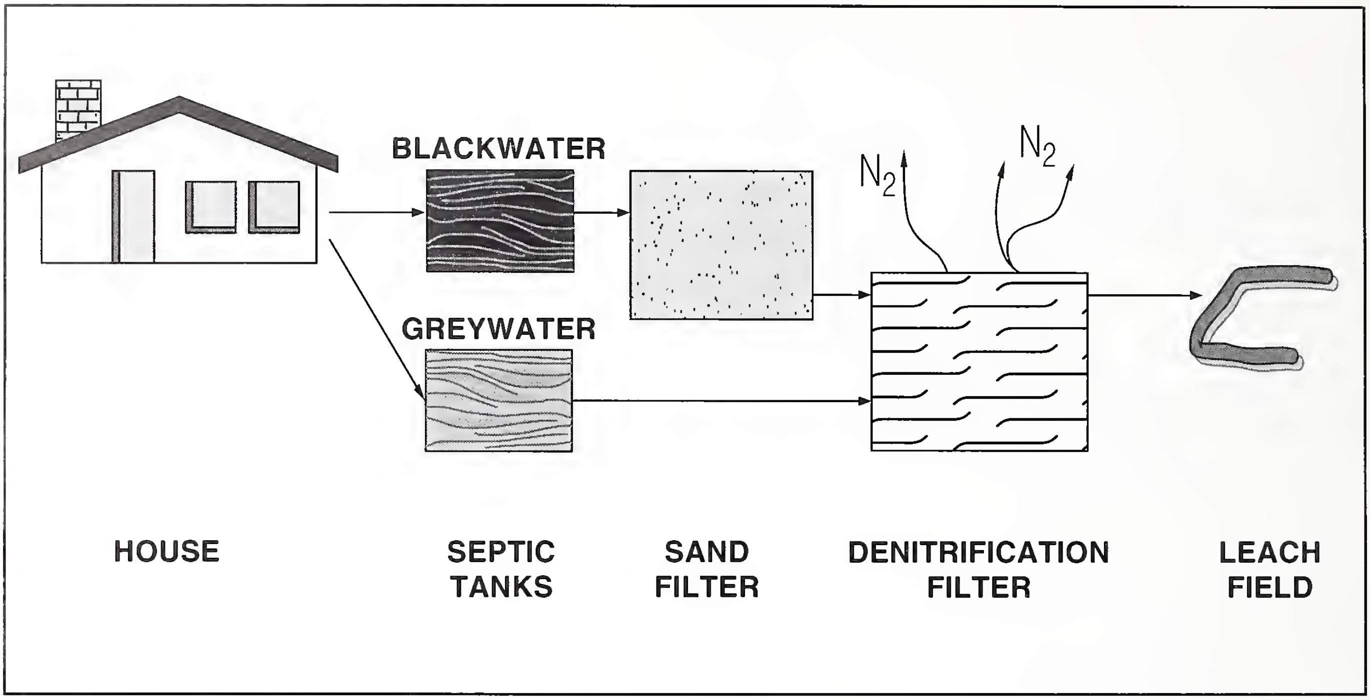


Figure 9.—*Schematic diagram of the RUCK system.*

RUCK System

The RUCK System (figure 9) is designed to convert 75 percent or more of the polluting nitrogen to gaseous nitrogen (the major constituent of the atmosphere). This is accomplished by separating the blackwater and greywater streams and passing the blackwater through a septic tank and then through a three-stage sand filter. The greywater is passed through a separate septic tank and is combined with the outflow of the sand filter in a rock-filled mixing tank (Denitrification filter). The effluent is sent to a disposal field, typically a subsurface leach field or an “In-Drain” system. (Reference 8.)

“Cycle-Let” System

The Cycle-Let on-site wastewater system, marketed by Thetford Systems, (figure 10) is a compact treatment system that is typically housed in the basement of the building it serves.

The process incorporates biological treatment, filtration, and disinfection. (Does not require chemical additives.)

The treated water is returned for reuse as flushwater for the building's toilets and urinals. Excess water may be used for landscape irrigation. With recycling and water conservation fixtures, the water use and wastewater discharge are typically reduced up to 95 percent. (Reference 9.)

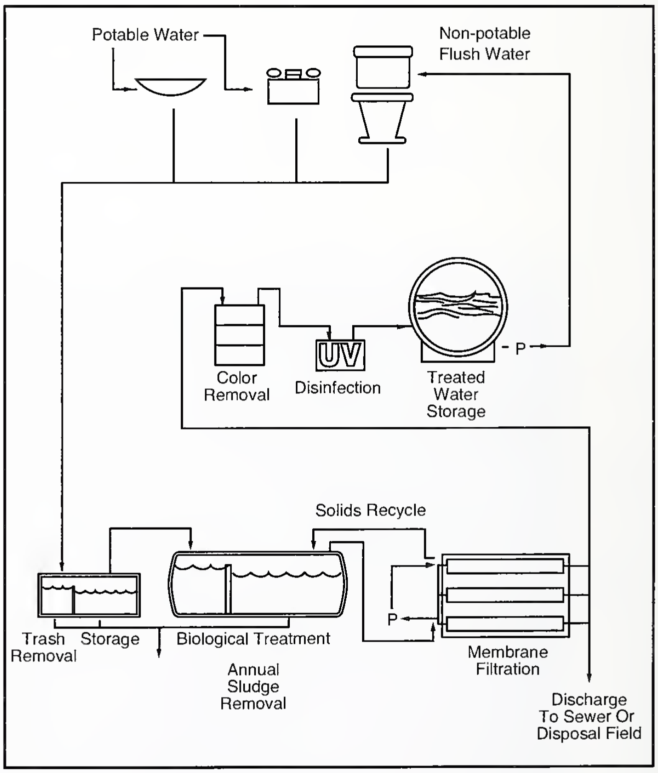


Figure 10.—"Cycle-Let" on-site wastewater system.

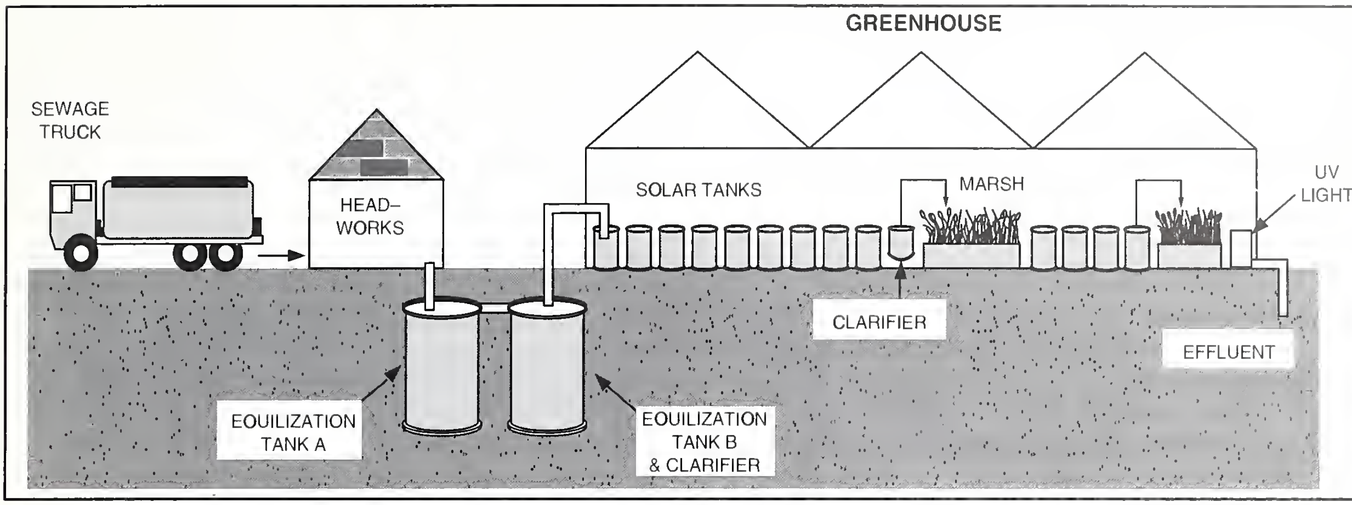


Figure 11.—*Solar aquatic system.*

Solar Aquatic System

Ecological Engineering Associates located in Marion, ME has developed the solar aquatic system (SAS) that duplicates, under controlled conditions, the natural water purification processes of freshwater wetlands. Wastewater is circulated inside a greenhouse through a series of clear tanks, each with its own aquatic ecosystem and marshes. In this treatment process, sunlight, oxygen, bacteria, algae, plants, snails and fish work together to purify the water. SAS uses aeration and mixing in the tanks to prevent sludge from settling. This enhances degradation of solids and results in fewer solids than conventional wastewater systems.

A typical SAS system (figure 11) consists of: (1) headworks where grit and large particles are removed, (2) vigorously aerated equalization tanks, (3) a gravity clarifier in which 84 percent of the solids are removed, (4) a greenhouse with rows of transparent tanks planted with willows and water hyacinths, (5) a gravity clarifier, piped in series, for removal and recycling of remaining solids, (6) a subsurface marsh filled with gravel and planted with reed canary grass and bulrush, (7) four tanks planted with a variety of vegetation, (8) a subsurface marsh, and (9) an ultraviolet disinfecting device. The effluent can be used for irrigation, groundwater replenishment, or discharged directly into surface waters. (Reference 10.)

Land Treatment

The land treatment or circular system relies on deep on-site treatment cells where wastewater is collected and submitted to 14 to 36 days of heavy aeration to oxidize the organic materials in the water. After the aeration period, the water is filtered and disinfected. Some of the water can then be used for irrigation. The remaining water, along with rain water, filters into underground rock formations, refilling the aquifer. About one acre of land is necessary to recycle the wastewater produced by nine or ten dwelling units.

DISPOSAL OPTIONS

Under proper conditions, wastewater may be safely disposed of onto the land, into surface waters or evaporated into the atmosphere by a variety of methods. The most commonly used methods for disposal of wastewater from campgrounds and administrative sites can be divided into three groups: (1) subsurface soil absorption systems, (2) evaporation systems, and (3) treatment systems that discharge to surface waters. Within each of these groups, there are various designs that may be selected based upon site factors encountered and characteristics of the wastewater. In some cases, a site limitation can be overcome by employing flow reduction or wastewater segregation devices. (Reference 2.)

On-site disposal methods discussed in this publication: (Reference 2.)

1. Subsurface Soil Absorption Systems
    - Trenches and Beds
    - Mounds
    - "In-Drains"
    - Drip Irrigation Systems
2. Evaporation systems
    - Evapotranspiration and Evapotranspiration-Absorption
    - Evaporation and Evaporation-Percolation Ponds
3. Treatment systems that discharge to surface waters
    - Rapid Infiltration
    - Overland Flow

Slow Rate Land Application
Constructed Wetlands and Aquatic Plant Systems
Spray Systems
Solar Aquatic Systems.

Subsurface Soil Absorption Systems

Trenches and Beds

Where site conditions are suitable, subsurface soil absorption is usually the preferred method of wastewater disposal due to its simplicity, stability and low cost. Under the proper conditions, the soil is an excellent treatment medium and requires little wastewater pretreatment. Partially treated wastewater is discharged below ground surface where it is absorbed and treated by the soil as it percolates to the groundwater. Travel through .61 to 1.22 meters (2 to 4 feet) of unsaturated soil is necessary to provide adequate removals of pathogenic organisms and other pollutants from the wastewater before it reaches the groundwater. Continuous application of wastewater causes a clogging mat to form at the infiltrative surface, thereby slowing the movement of water into the soil. This can be beneficial because it helps to maintain unsaturated soil conditions below the clogging mat. (Figures 12 and 13.) (Reference 2.)

If gravity feeding the leach field is not possible, a small sewage pump and small diameter pressure lines can transport the effluent to an area for disposal. Vacuum sewer systems have also been used to convey the effluent for disposal. It is also possible to design a leach field with minimum disturbance of the existing plants and trees.

Most states require an area to be set aside equal to the leach field area for use should the original leach field fail. Some subsurface absorption facilities are designed so that one-half of the field is active while the other half rests and, after a set period of time, the operation is reversed. This type system can be operated automatically by using a dosing siphon.

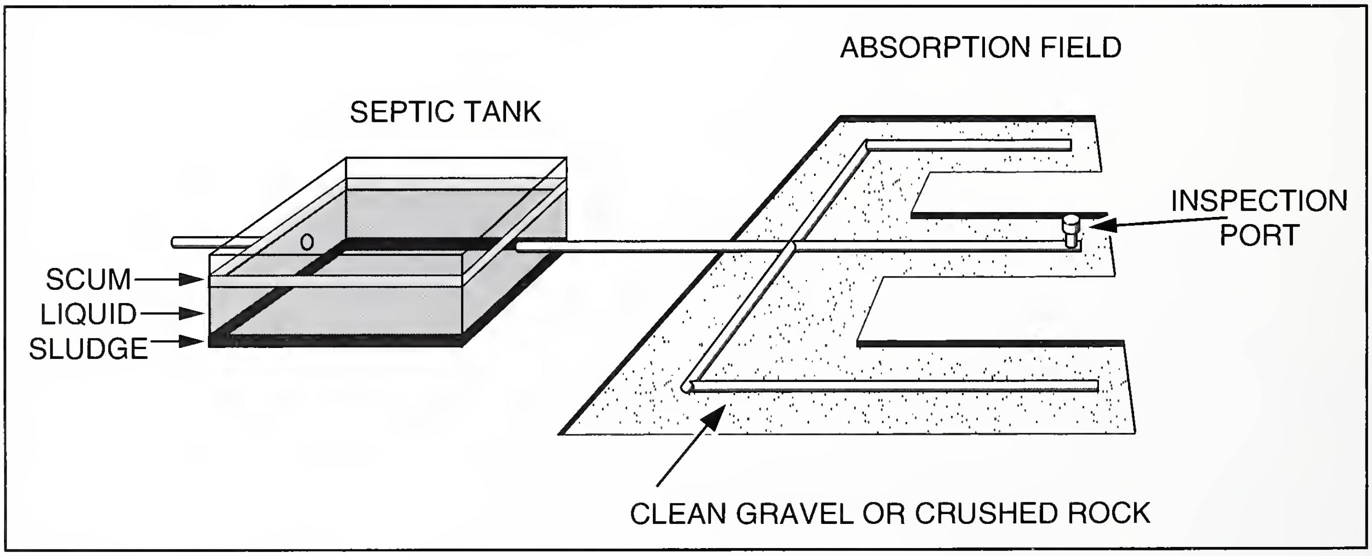


Figure 12.—*Septic tank and gravel absorption trench.*

Septic Tank and Gravel Absorption Trench

- Suitable on level land with adequate soil depth above the water table.
- In the septic tank, heavy solids in the greywater settle and greases float to the top.
- Bacteria breaks down some solids.
- The liquid flows from the tank through a closed pipe into gravel absorption trench.
- The liquid seeps into the soil.
- Bacteria and oxygen purify the liquid as it slowly moves through the soil.

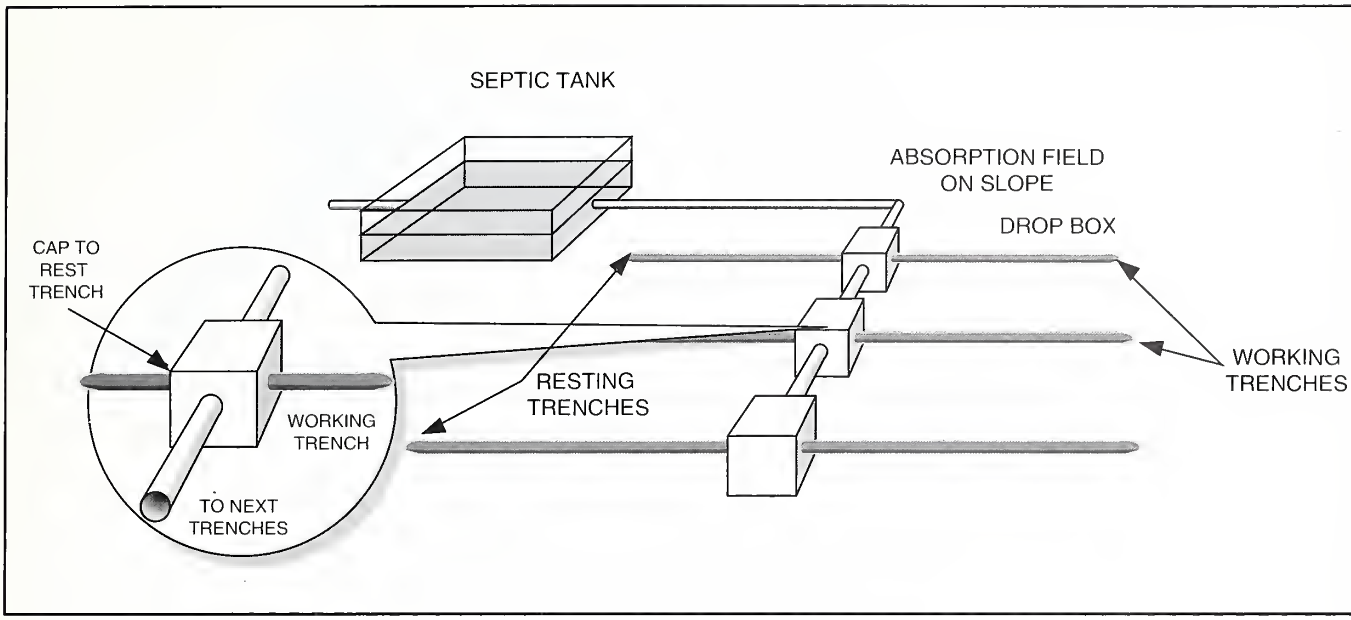


Figure 13.—*Septic tank with serial distribution.*

<u>Septic Tank With Serial Distribution</u>

- Suitable on gently to steeply sloped sites.
- Starting with the highest, each trench fills completely, then overflows through one drop box to the next.
- The effluent floods all soil surfaces.
- The drop box enables inspection of thesystem and control of discharge into each trench which makes resting of some trenches possible to increase their absorption capability.

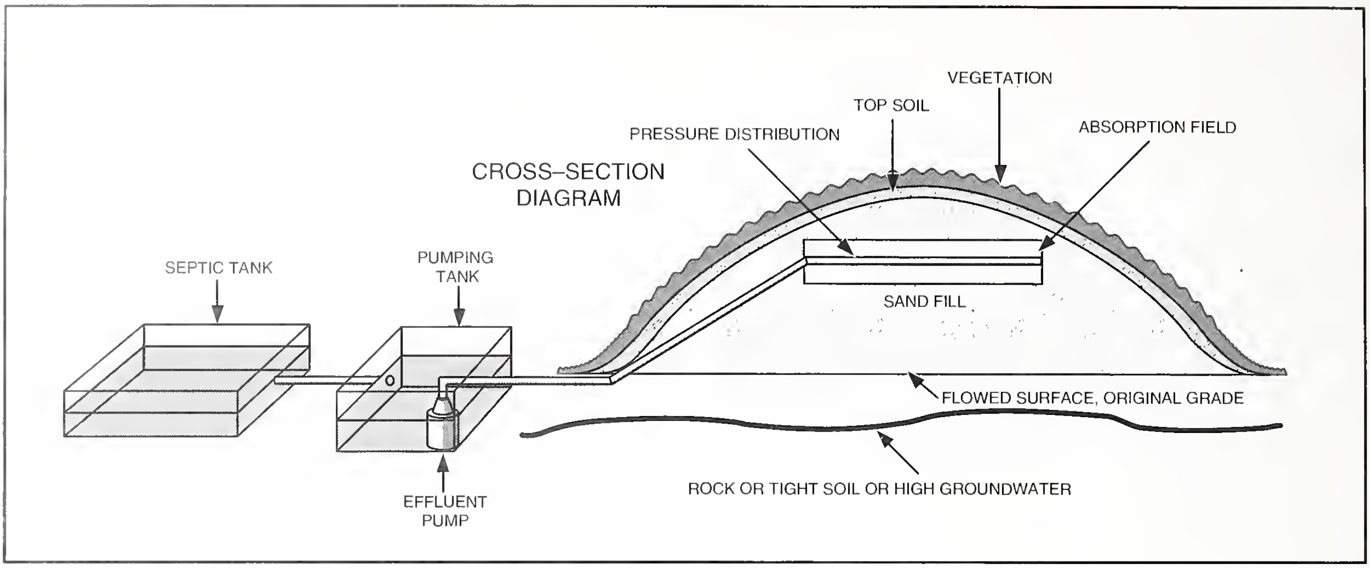


Figure 14.—*Septic tank and mound system.*

Septic Tank and Mound System

- Suitable for areas with high ground water, high bedrock, or tighter clay soils.
- Pump dose effluent into a gravel bed or trenches on top of a bed of sand.
- Sandy soil carefully placed above the plowed ground surface treats the effluent before it moves into the natural soil.

Mounds

A mound system (figure 14) is a soil absorption system elevated above the natural soil surface in a suitable fill material. Mounds are used to overcome site restrictions (slowly permeable soils, shallow permeable soils over creviced or porous bedrock or permeable soils with high water tables). The mound system consists of suitable fill material, an absorption area, a distribution network, a cap and top soil. The effluent is pumped or siphoned into the absorption area through a distribution network located in the upper part of the coarse aggregate. It passes through the aggregate and infiltrates the fill material. Treatment of the wastewater occurs as it passes through the fill material and the unsaturated zone of the natural soil. (Reference 2.)

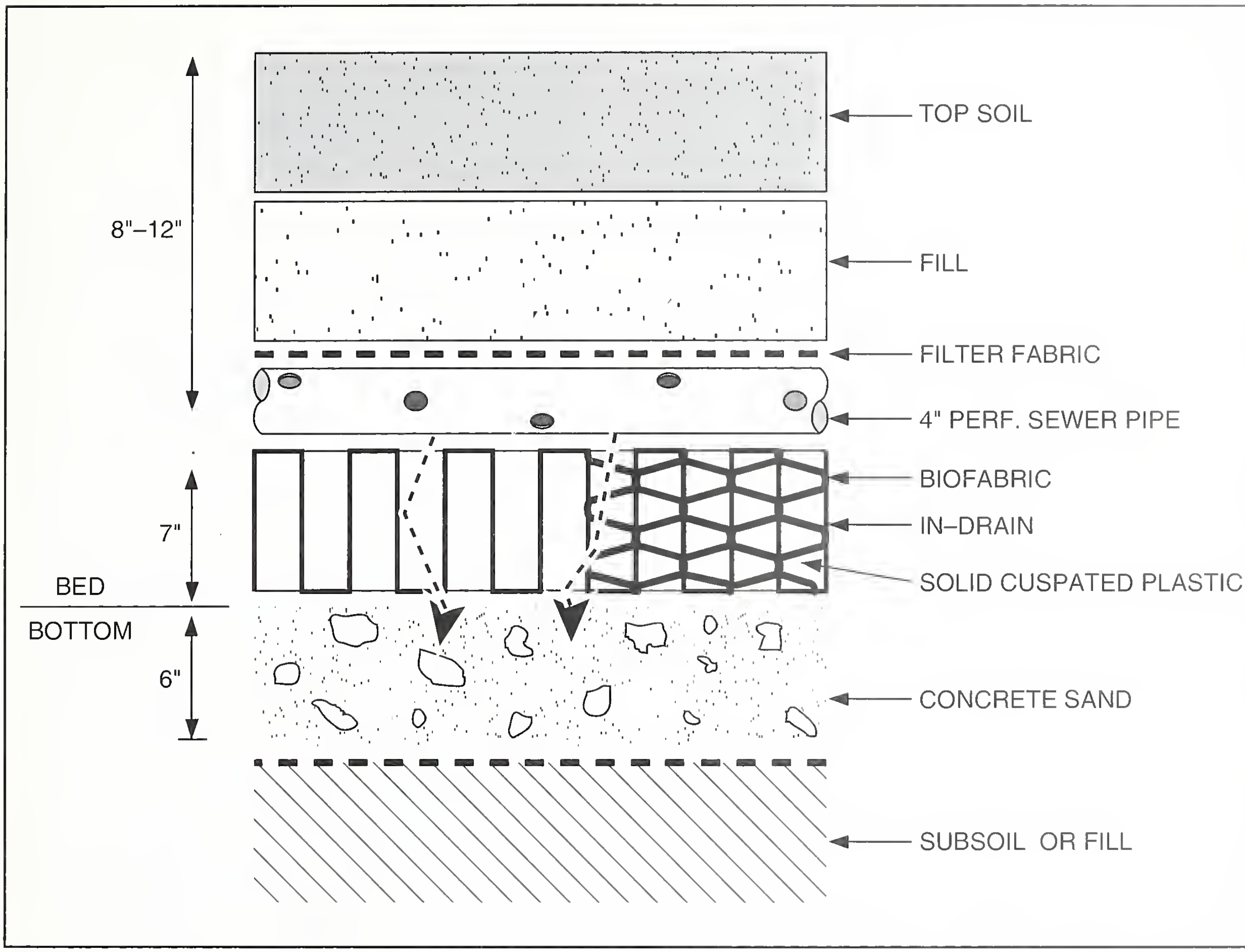


Figure 15.—*"In-Drain" system.*

In-Drains

The "In-Drain" system is an upgrade from conventional stone, aggregate, or other leach-field systems. The "In-Drain" design (figure 15) is based on proven enhancements. Evapotranspiration, oxygen transfer, biodegradation, soil treatment and long term operation are accomplished by using biotextile prefiltration and controlled soil loading. The installation is protected from long term siltation with a geotextile fabric cover. The advantage of the "In-Drain" system is the multiple vertical infiltrating surfaces that provide approximately six times the area per square foot of the bottom area. "In-Drains" are constructed of multiple fins securely banded together into a rigid module. The soil directly below the modules never develops a significant biomat layer thus allowing "In-Drain" leach fields to be approximately one-third of the size of conventional rock and pipe systems. (Reference 12.)

Drip Irrigation Systems

The State of California added Appendix J to the California Plumbing Code (December 1993) which allows greywater subsurface landscape irrigation on the site of the building or structure that discharges the greywater. The irrigation field construction may be subsurface drip irrigation, mini-leach field or other equivalent irrigation methods which discharge greywater in a manner which ensures that the greywater will not surface. Before a permit is issued, the following requirements must be submitted to the administrative authority: (1) Drawings and specifications, (2) a plot plan, (3) details of construction, and (4) a log of soil formations. Surge tanks are required for all systems and a filter is required for the subsurface drip irrigation system. No disinfection is required. (Reference 13.)

The State of Georgia has a drip irrigation draft proposal submitted for approval to allow land application of wastewater. The system is designed so there is no direct discharge to surface waters. The irrigated wastewater transpires to the atmosphere, or enters the groundwater through percolation. Properly designed and operated wastewater irrigation systems produce percolate water of high quality which protects ground and surface water resources. The actual facilities will consist of aerobic or anaerobic pretreatment followed by surface or subsurface distribution systems utilizing controlled flow distribution emitters.

Criteria and processing for Georgia Environmental Protection Division (EPD) approval of slow rate land treatment systems includes: (Reference 14.)

1. Letter of intent and evaluation report submitted by owner
2. Site inspection conducted by EDP
3. Environmental Information Document
4. Design Development Report
5. Application for permit
6. Public notice
7. Permit issued
8. Plans and Specifications
9. Plan of Operation and Management
10. Certification of Construction Completion
11. Authorization to commence operation at design flow.

Evaporation Systems

Evapotranspiration and Evapotranspiration-absorption

Evapotranspiration (ET) beds can be used to dispose of wastewater to the atmosphere so no discharge to surface or groundwater is required. On-site ET disposal normally consists of a sand bed with an impermeable liner and wastewater distribution piping. The surface of the sand bed may be planted with vegetation. Wastewater entering the bed is normally pretreated to remove settleable and floatable solids. An ET bed functions by raising the wastewater to the upper portion of the bed by capillary action in the sand and evaporating it to the atmosphere. In addition, vegetation transports water from the root zone to the leaves, where it is transpired. (See figure 16, left side)

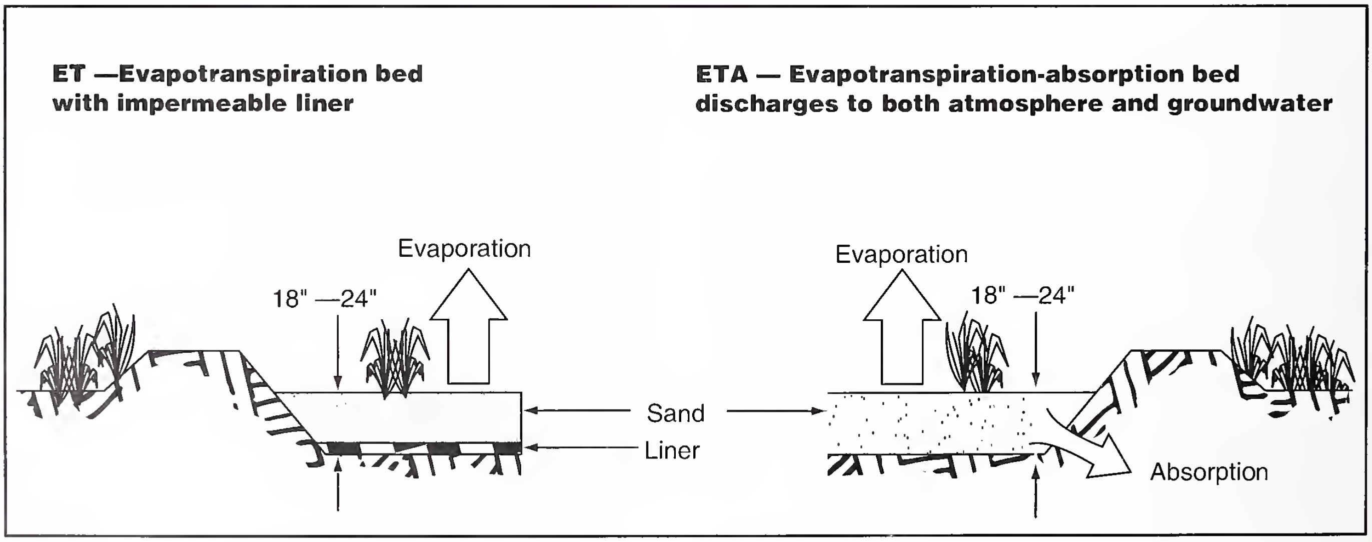


Figure 16.—*Lagoons without external mechanical energy. Same as facultative lagoon except shallower depth suitable for warm climate. (Reference 1.)*

On-site systems utilizing ET disposal are primarily used when geological limitations prevent the use of subsurface disposal and where discharge to surface waters is not permitted or feasible. Climatic condition is the most significant constraint on the use of ET systems. The evaporation rate is primarily controlled by factors such as precipitation, wind speed, humidity, solar radiation, and temperature.

Evapotranspiration-absorption (ETA) beds (right side of figure 16) are a modification of the ET concept which discharges to both the atmosphere and to ground-water. In ETA systems, the impervious liner is omitted and a portion of the wastewater is disposed of by seepage into the soil. ETA systems are generally used where slow permeable soils are encountered.

Evaporation and evaporation-infiltration ponds (lagoons)

An evaporation (E) or evaporation-infiltration (E-I) lagoon can be used in most locations that have enough available land. Actual application of these lagoons is generally limited to rural areas where subsurface disposal is not possible (figure 17).

In addition, use of evaporation-infiltration lagoons is not appropriate in areas where percolation might contaminate groundwater supplies, such as in areas of shallow, creviced bedrock or high water tables. Use of both types of lagoons, especially evaporation lagoons, is favored by the large net evaporation potentials found in arid regions.

If soil conditions permit, cuts and fills should be balanced at the site. Lagoon bottoms may need infiltration control in permeable soils; use clay, plastic liner, asphalt or polyphosphetic application. (See figure 18 and Reference 1.)

The major factors affecting evaporation performance and evaporation-infiltration lagoons are climatic: (sunlight, wind circulation and humidity) soil permeability (E-I only), salt accumulation (E only), hydraulic loading, inlet configuration and construction techniques.

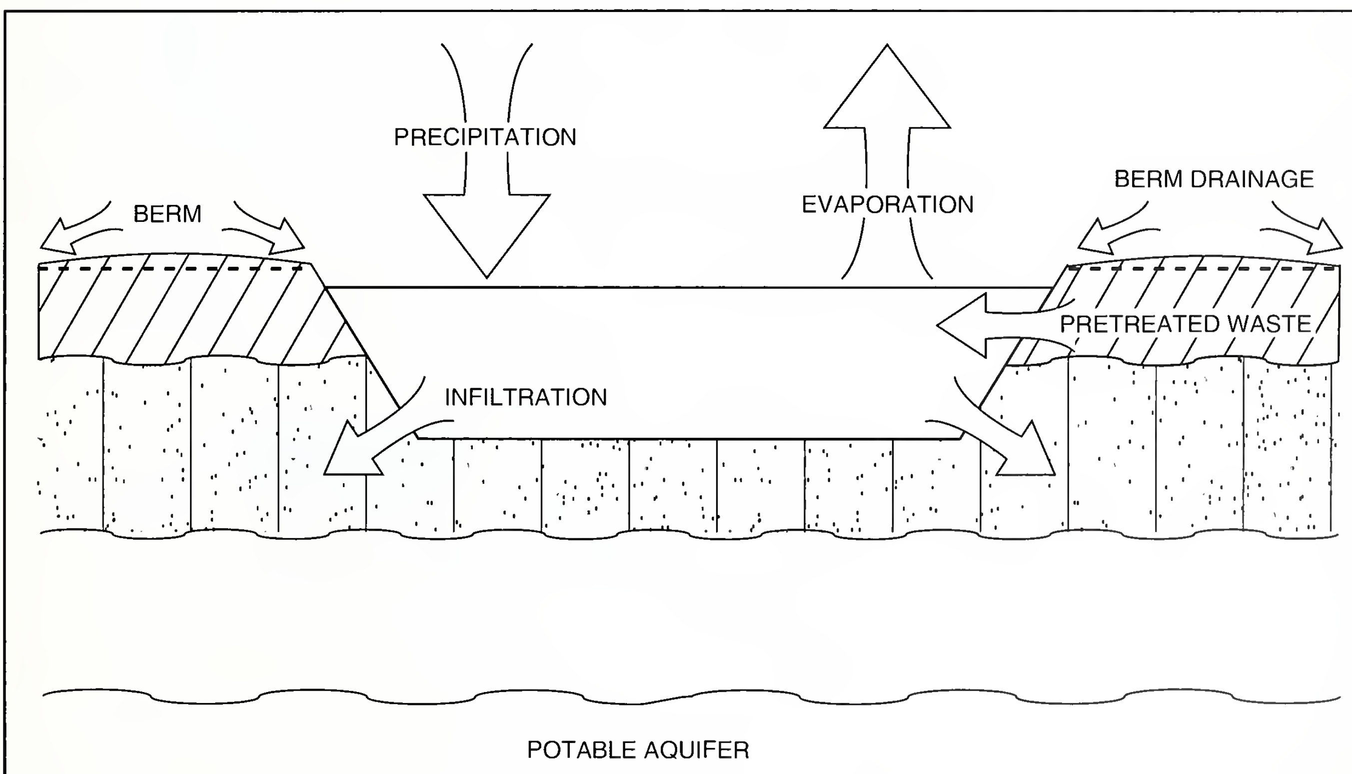


Figure 17.—*Bermed infiltration pond (not to scale).*

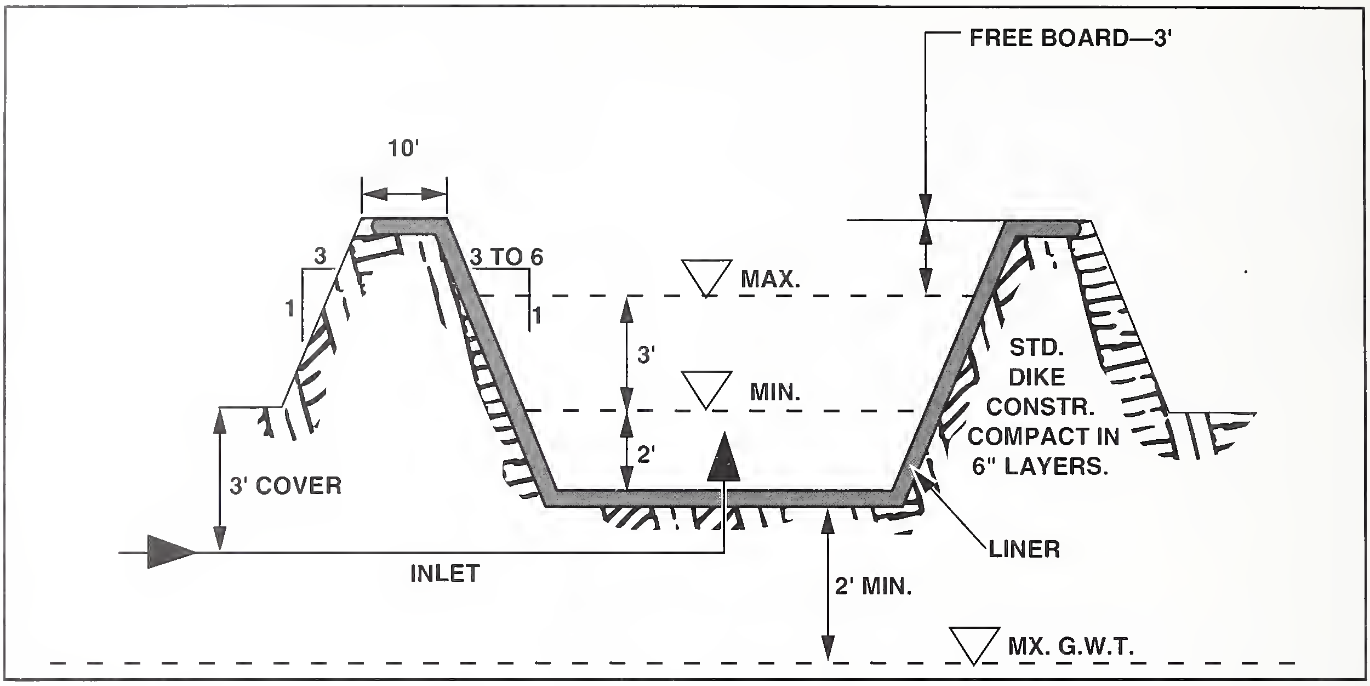


Figure 18.—*Evaporation lagoon (not to scale).*

Treatment Systems That Discharge To Surface Waters

Rapid Infiltration

Rapid infiltration is a soil-based wastewater treatment method that typically consists of a series of earthen basins with exposed soil surfaces designed for a repetitive cycle of flooding, infiltration/percolation and drying. (Figures 19a and 19b.) (Reference 4.)

The method depends on a relatively high rate of wastewater infiltration into the soil and percolation through a vadose or unsaturated soil zone below the infiltrative surface before recharge to the ground-water table. System design is based on the capability of soils to provide acceptable treatment before the percolate reaches the groundwater.

Rapid infiltration is a proven technology for year-round treatment of domestic, municipal, and other organic wastewaters. Its application is primarily limited by soil characteristics, ground-water impacts and land costs.

Two schematics of rapid infiltration facilities:

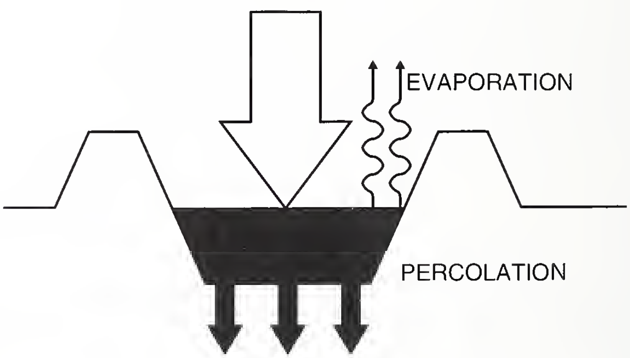


Figure 19a.—*Hydraulic pathway.*

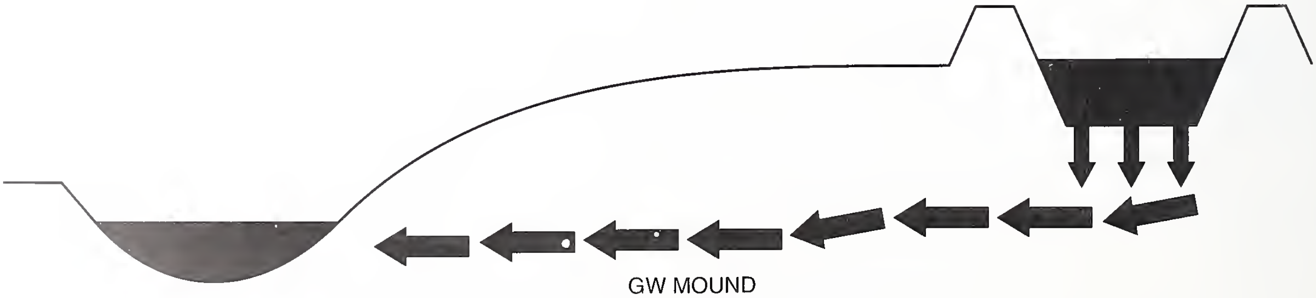


Figure 19b.—*Natural drainage into surface waters.*

Rapid infiltration is a method of land application providing very favorable removal of the conventional wastewater parameters—including ammonia—that is simple to operate and requires only a minimum of operator intervention. Moreover, it requires less land area than other land application methods and may be operated year round. It is a "zero-discharge" method that provides ground-water recharge rather than requiring an outfall for direct discharge to surface water. Frequently, renovated wastewater is recovered via wells for reuse in irrigation.

Overland Flow

Overland flow (figure 20) is a land application method of wastewater treatment with a point discharge to surface water. The technology consists of a series of uniformly sloped, vegetated terraces with a wastewater distribution system located at the top of the terrace and a runoff collection channel at the bottom. Facilities for wastewater storage during wet or freezing weather are also provided. In overland flow, wastewater is applied intermittently across the top of the terraces and allowed to sheet flow over the vegetated surface to the runoff collection channel. The system is not designed for soil percolation, though some percolation may occur. A tailwater return system (a collection pond, pump and return pipeline) can be provided to contain and recycle runoff from the site due to excessive application or precipitation.

Treatment is achieved primarily through sedimentation, filtration, and biochemical activity as the wastewater flows through the vegetation on the terraced slope.

Overland flow from seasonal recreational and administrative sites with organic wastes is well suited for wastewater treatment. It provides secondary or advanced secondary treatment, yet is relatively simple and inexpensive to operate. Of the land application methods of wastewater treatment, overland flow is the approach least restricted by soil characteristics. However, this method does require a relatively impermeable soil for conventional operation. Public access into the site must be restricted and fencing is usually required. (Reference 4.)

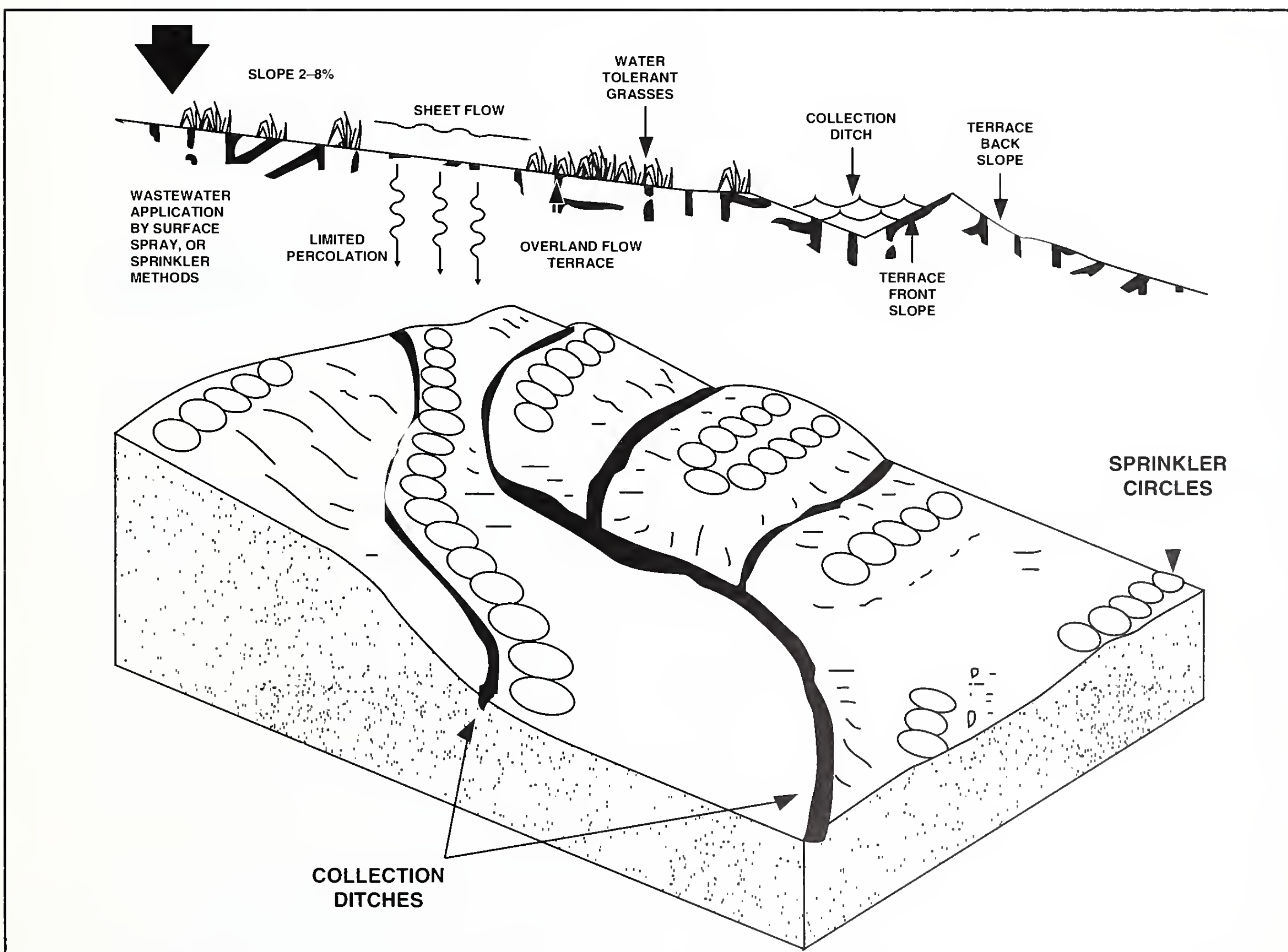


Figure 20.—*Schematics of an overland flow system.*

Two schematics of slow rate land application systems:

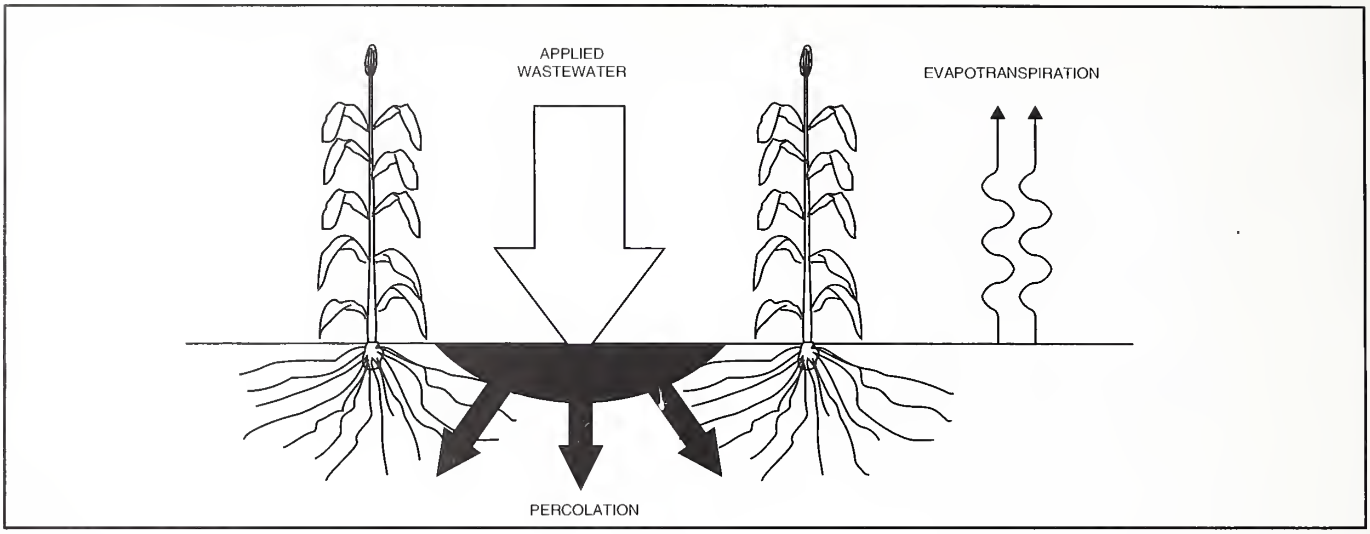


Figure 21a.—*Application pathway.*

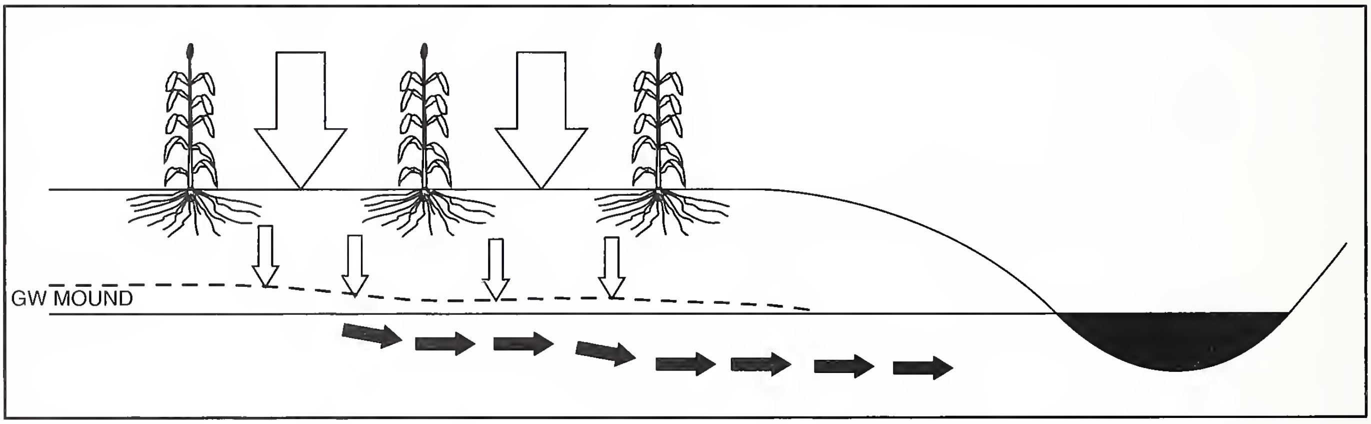


Figure 21b.—*Subsurface Pathway.*

Slow Rate Land Application

Slow rate land application (figure 21 a & b) is a soil-based wastewater treatment method designed to apply intermittently unchlorinated primary or secondary treatment effluent at a controlled rate to a vegetated soil surface of moderate to slow permeability. The wastewater is applied via sprinklers or flooding of furrows. Following application, the wastewater infiltrates the land surface and percolates through the soil profile to the ground-water table.

A tailwater return system is usually provided (may in some cases be required) to contain and recycle wastewater runoff from the site due to excessive application or precipitation. It consists of a collection pond, pump and return pipeline.

A storage reservoir must also be provided for adverse weather conditions, crop cultivation and harvesting, and emergencies.

Slow rate land application is well suited for treatment of wastewater from seasonal recreational and administrative sites. It can provide an economic return from the reuse of water and nutrients for irrigation of landscaped areas or ground-water recharge.

Of the various land treatment methods, slow rate land application is the least limited by surface slopes. Public access into the site may be restricted. Fencing is usually required. (Reference 4.)

Constructed Wetlands and Aquatic Plant Systems

Wetlands are those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to maintain saturated conditions. These can be either existing natural wetlands (e.g., marshes, swamps, bogs, cypress domes and strands, etc.) or constructed wetland systems.

Constructed systems can range from creation of a marsh in a natural setting (where one did not exist before) to intensive construction involving earth moving, grading, impermeable barriers, or erection of containers such as tanks or trenches. The vegetation that is introduced or emerges from these constructed systems will generally be similar to that found in the natural wetlands.

There are three basic functions of wetlands that make them potentially attractive for Forest Service wastewater treatment.

1. Physical entrapment of pollutants through sorption in the surface soils and organic litter.
2. Utilization and transformation of elements by microorganisms.
3. Low energy and low maintenance requirements to attain consistent treatment levels.

One technical approach is to construct artificial ecosystems as a functional part of wastewater treatment. Wastewater has been treated and reused successfully as a water and nutrient resource in agriculture, silviculture, aquiculture, golf course and green belt irrigation. The conceptual change that has allowed these innovative processes is to approach wastewater treatment as "water pollution control" with the production of useful resources (water and plant nutrients) rather than as a liability.

The interest in aquatic wastewater treatment systems can be attributed to three basic factors:

1. Recognition of the natural treatment functions of aquatic plant systems and aquatic plant systems and wetlands, particularly as nutrient sinks and buffering zones
2. In the case of wetlands, emerging or renewed application of aesthetic, wildlife, and other incidental environmental benefits associated with the preservation and enhancement of wetlands
3. Rapidly escalating costs of construction and operation associated with conventional treatment facilities.

A positive feature of a constructed wetland systems is that they can operate in cold as well as warm climates.

In considering the application of wastewaters to wetlands, the relationship between hydrology and ecosystem characteristics must be recognized. Factors such as source of water, velocity, flow rate, renewal rate and frequency of inundation have a major bearing on the chemical and physical properties of the wetland substrate. In turn these properties influence the character and health of the ecosystem, as reflected by species composition and richness, primary productivity, organic deposition and flux, and nutrient cycling. Water movement through wetlands tends to have a positive impact on the ecosystem. Rather than wasting water, upland swamps appear to save water and indirectly promote more stable regional production.

Constructed wetlands are comparatively shallow (typically less than 0.6m (2 feet) bodies of slow-moving water in which dense stands of water tolerant plants such as cattails, bulrushes or reeds are grown. In man-made systems, these bodies are artificially created and are typically long, narrow trenches or channels.

Almost all natural wetlands are waters of the United States and, as such, a permit is required for any discharge to them. The water quality requirements for this discharge are specified by the applicable Federal, State and/or local agencies and typically are equal to secondary effluent standards.

On the other hand, constructed wetlands designed and built for the express purpose of treated municipal wastewater are not designated as waters of the United States. The major costs and energy requirements for constructed wetlands are associated with preapplication treatment, pumping and transmission to the site, distribution at the site, minor earthwork, and land costs. In addition, a constructed system may require the installation of a barrier layer to limit percolation to groundwater and additional containment structures in case of flooding.

Types of Constructed Wetlands

Constructed wetlands include free water surface systems (FWS), as well as the more recently developed subsurface flow systems (SFS). The latter system involves subsurface flow through a permeable medium. The "root-zone method" and "rock-reed-filter" are other names for these systems that have been used. Because emergent aquatic vegetation is used in these systems, they depend on the same basic microbiological reactions for treatment. The media type (soil or rock) affects the hydraulics of the system.

Free Water Surface Systems (FWS)

These systems typically consist of basins or channels, with some type of subsurface barrier to prevent seepage, soil, or another suitable medium to support the emergent vegetation, and water at a relatively shallow depth flowing through the unit. The shallow water depth, low flow velocity, and presence of the plant stalks and litter regulate water flow and, especially in long, narrow channels, minimize short circuiting.

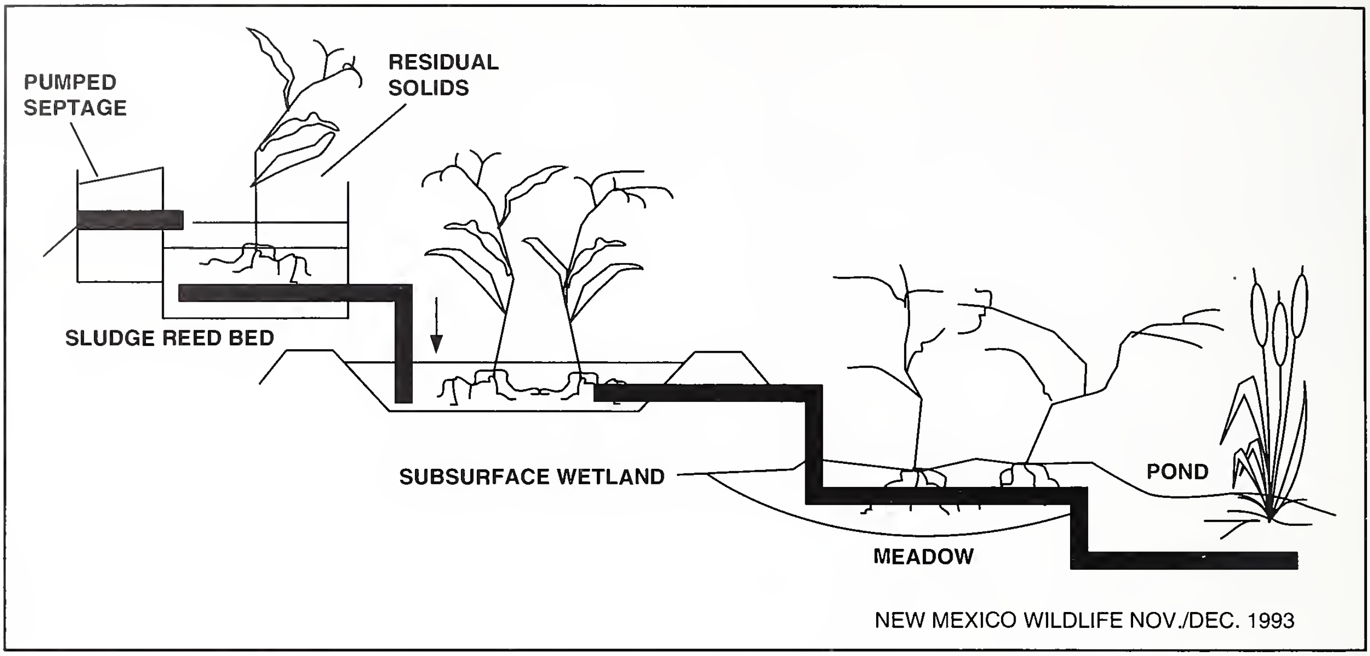


Figure 22.—*Subsurface flow systems.*

Subsurface Flow Systems (SFS)

A SFS wetland is a constructed wetland consisting of a trench or bed underlain with an impermeable layer of clay or a synthetic liner. The bed contains media which will support the growth of emergent vegetation. The system is built with a slight inclination (1 to 3 percent) between inlet and outlet. Primary or pond effluent is introduced into the end of the system where it flows into a transverse channel filled with broken stones.

Alternatively, the inlet channel can be perforated or gated pipe. From there the wastewater flows horizontally through the rhizosphere of the wetland plants. During the passage of the wastewater through the rhizosphere, the wastewater is treated by filtration, sorption and precipitation processes in the soil and by microbiological degradation.

The resulting physical/chemical and biochemical processes correspond to the mechanical and biological processes in conventional mechanical treatment systems including denitrification. The effluent is collected at the outlet channel which is often filled with coarse gravel and may be discharged directly into the receiving water. (Reference 5.) (See figure 22.)

Spray Systems

The successful use of spray irrigation requires a careful investigation of the proposed disposal site. A variety of factors affect spray field operation, including the slope of the surface, application rate, surface soil permeability, subsurface soil characteristics, type of cover vegetation, period of time of application, total quantity applied during one time period, the chemical composition of the soil and characteristics of the effluent applied.

NOTE: Figure 23 shows a system where the effluent from a septic tank is being used. Timed sprinklers can apply the effluent at night or below the soil surface to plants and trees in a treatment area. The land application is more suitable for a warm and dry climate. A cautionary note must be added that wastewater treatment by land application may require certain state/local regulatory constraints. If land application is found an acceptable option, it is recommended that the treated site be fenced.

Solar Aquatic Systems

Solar Aquatic Systems, because of the high quality treatment of the wastewater, can discharge directly into surface waters. (Refer to **Page 11** for more information on this system.)

TERTIARY TREATMENT

Tertiary treatment is the further processing or polishing of the wastewater effluent from a secondary process. It is designed to remove dissolved and suspended material by means other than simple gravitation or mechanical screening. Tertiary processes are often variations of primary or secondary processes but may also be entirely different. Tertiary removal of suspended solids is generally accomplished by microscreening or filtration. Most rapid sand or pressure filters must be backwashed, and require regular maintenance. Slow sand filters must have the filter surface periodically scraped.

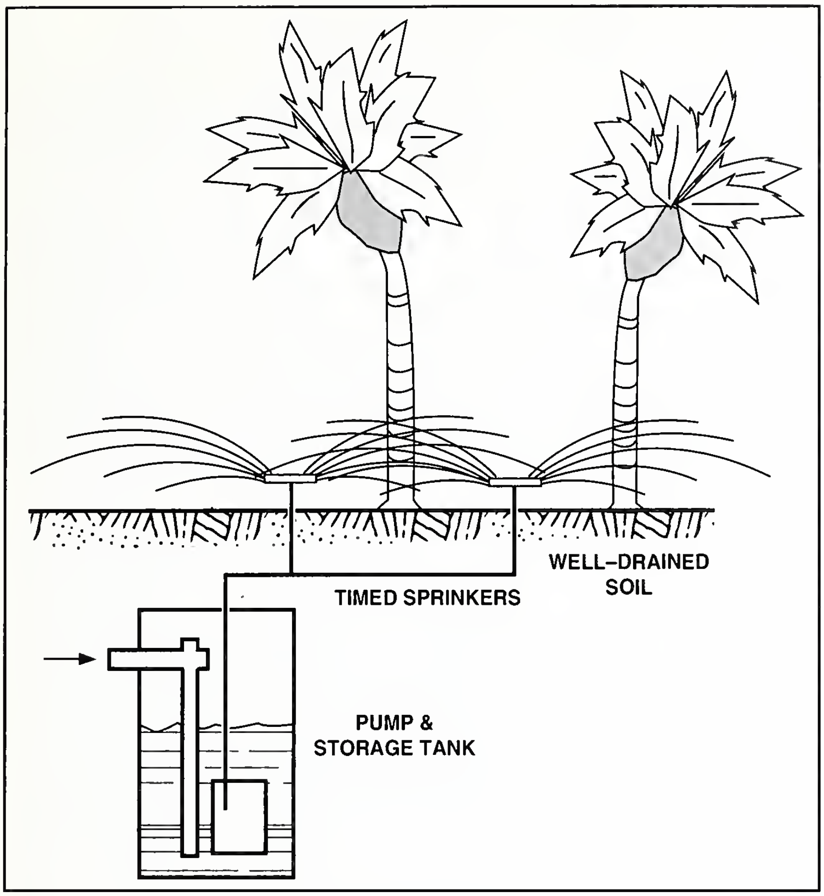


Figure 23.—*Spray system using effluent from septic tank.*

Tertiary treatment is generally used in cases where the effluent is going to be discharged directly into surface waters.

SUMMARY AND CONCLUSIONS

Large segments of the United States and the world are facing a critical water supply shortage because of population and economic growth, persistent drought conditions and a lack of adequate planning for future water needs. Historically, public policy and health codes have mandated centralized collection and treatment of all wastewater. Many states and counties currently are reexamining their policies and codes regarding on-site wastewater treatment and recycling.

Fortunately, solutions are available which can help alleviate these problems by reducing water consumption in an environmentally acceptable manner. Typical of the devices that can help are low-flow toilets, low-flow shower heads, and faucet flow restrictors. The Energy Policy Act of 1992, Public Law 102-486, requires the use of energy conserving devices whenever possible. Further reductions can be achieved by on-site wastewater treatment and recycling systems that permit reuse of greywater for landscape irrigation and toilet flushing.

Dual distribution systems, with reclaimed water for the nonpotable supply, are increasingly being adopted where water resources are limited. Forest Service planners/designers should consider dual distribution systems among the options available to them for addressing water supply needs, water pollution control problems, or both, where regulations allow.

The use of constructed wetlands for greywater and wastewater treatment is a natural transition for the Forest Service with its emphasis on ecosystem management. Constructed wetlands provide cost-effective, innovative and environmentally sensitive alternatives for wastewater treatment. Wetlands projects are truly multipurpose; incorporating water treatment, recovery and reuse with wildlife values, public education, and enhancement of environmental resources. Wetlands have long been recognized for providing fish/wildlife habitat and preservation of threatened and endangered species. They can also contribute to increased environmental awareness through recreational and educational opportunities, such as hiking, bird watching, and picnicking. Interpretive centers, nature trails, and guided tours can be included to increase the public awareness, education and enjoyment opportunities.

When multipurpose wetlands are included as a part of a total water resources management program, they can provide water quality treatment and groundwater recharge benefits. Also, multipurpose wetlands, when properly designed, operated and maintained, offer an attractive alternative to the energy-intensive physical, chemical and biological treatment facilities needed to meet water quality standards on reclaimed water reuse. If the water produced from the wetlands is of suitable quality to be recharged into groundwater aquifers, diminishing groundwater resources would be supplemented, or in some areas, recharged water could be applied as a part of a comprehensive groundwater remediation program.

RECOMMENDATIONS

Many issues can be resolved by using new technologies and innovative approaches to water resources management. It is best to approach wastewater treatment as "water reclamation" that produces a useful resource (water and plant nutrients) rather than as a liability. The use of on-site greywater recycling and combined wastewater treatment and recycling systems should always be considered.

Table 2.—*Site Constraints*

Method	Soil Permeability			Depth to Bedrock			Depth to Water Table		Slope			Small Lot Size
	Very Rapid	Moderate Rapid	Slow Very Slow	Shallow And Porous	Shallow And Nonporous	Deep	Shallow	Deep	0-5%	5-15%	15%	
Trenches and Beds		X	X[1]			X		X	X			X[2]
Mounds	X	X	X	X	X		X		X	X		X
In-Drains	X	X	X		X	X		X	X	X		X
Drip Irrigation Systems	X	X	X	X	X	X	X	X	X	X	X	
Evapotranspiration & Evapotranspiration-Absorption			X[3]	X	X		X		X	X[4]		
Evaporation & Evaporation-Percolation Ponds		X	X[3]		X		X		X	X[4]		
Rapid Infiltration	X	X				X		X	X	X		
Overland Flow		X	X	X	X	X	X	X	X	X[4]		
Slow Rate Land Application		X	X			X		X	X	X[4]	X[4]	
Constructed Wetlands	X	X	X	X	X	X	X	X	X			
Spray Systems	X	X	X	X	X	X	X	X	X	X	X	
Solar Aquatic Systems	X	X	X	X	X	X	X	X	X			X

X means system can function effectively with that constraint

[1]Trenches only.
[2]Flow reduction suggested.
[3]High evaporation potential required.
[4]Recommended for south-facing slopes only.

GLOSSARY

The following words and terms, when used in this report, shall have the following meanings, unless the context indicates otherwise.

Aerobic digestion - The bacterial decomposition and stabilization of sewage in the presence of free oxygen.

Anaerobic digestion - The bacterial decomposition and stabilization of sewage in the absence of free oxygen.

Blackwater - All sewage (other than greywater) that contains sufficient human or animal wastes to require the water to be treated prior to disposal.

Collection system - An on-site sewage collection network connected to a treatment and disposal system that is designed to serve two or more sewage generating units.

Effluent - Sewage, water, or other liquid, partially or completely treated or in its natural state, flowing out of a reservoir, basin, or treatment plant.

Evapotranspiration (ET) system - A sewage facility which relies on soil capillarity and plant uptake to dispose of treated effluent through surface evaporation and plant transpiration.

Floodplain (100 year) - That area along a stream inundated during the time the stream is subject to the statistical 100-year flood.

Geotextile filter fabric - A non-woven fabric suitable for wastewater applications.

Greywater - Wastewater (sewage) from dishpans, clothes washing machines, showers, bathtubs, hand washing lavatories, and sinks not used for the disposal of excreted wastes or hazardous or toxic ingredients.

Injection well - A hole drilled into permeable soil which is intended to receive either raw sewage or the effluent from some form of sewage treatment process.

Low-flow fixtures - Shower heads, faucets, valves, and hose bibs that allow only small quantities of water to pass through.

Low-flow toilets - Toilets that use 1.6 gallons or less per flush.

Mound system - A soil absorption system which is installed in or below an artificially created mound of earth.

National Sanitation Foundation (NSF) - International Testing Laboratories, Ann Arbor, MI. It is a neutral agency, serving government, industry and consumers in achieving solutions to problems relating to public health and the environment. NSF standards specify the requirements for the products, and may include requirements relating to materials design, construction, and performance.

On-site sewage system - A single or combination of treatment devices and disposal facilities that is used only for the disposal of wastewater on the site.

Scum - A mass of organic and/or inorganic matter which floats on the surface of sewage.

Septic tank - A watertight covered receptacle designed to receive, store and provide treatment to domestic sewage. Its function is to separate solids from the liquid, digest organic matter under anaerobic conditions, store the digested solids through a period of detention, and discharge the clarified liquid effluent to be disposed of in an approved sewage disposal facility.

Sewage - Water which contains, or which has been in contact with, organic or inorganic contaminants such as: human or animal wastes, vegetable matter, cooking fats and greases, laundry and dishwashing detergents, and other chemicals, compounds and waste products.

Sludge - A semi-liquid mass of partially decomposed organic and inorganic matter which settles at/or near the bottom of a receptacle containing sewage.

Soil-absorption system - A subsurface method for the disposal of partially treated sewage which relies on the soil's ability to absorb moisture and allow its dispersal by lateral and vertical movement through and between individual soil particles.

Subsurface sewage facility - A system designed to treat sewage and distribute the treated sewage effluent into a below ground-level disposal area.

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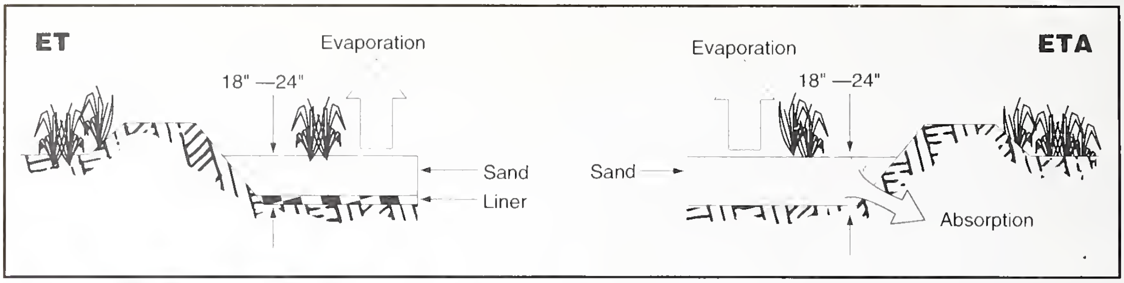
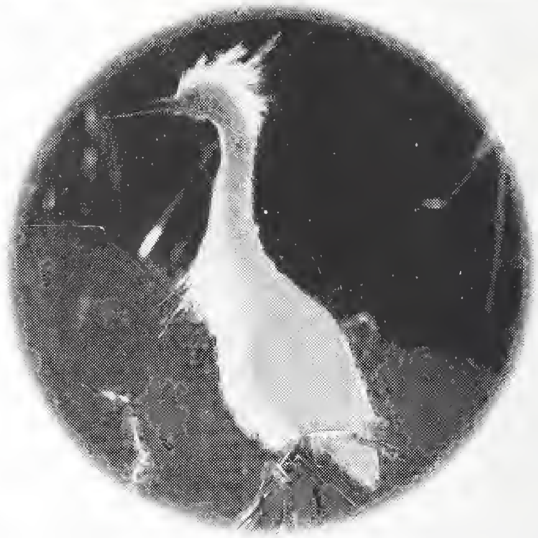
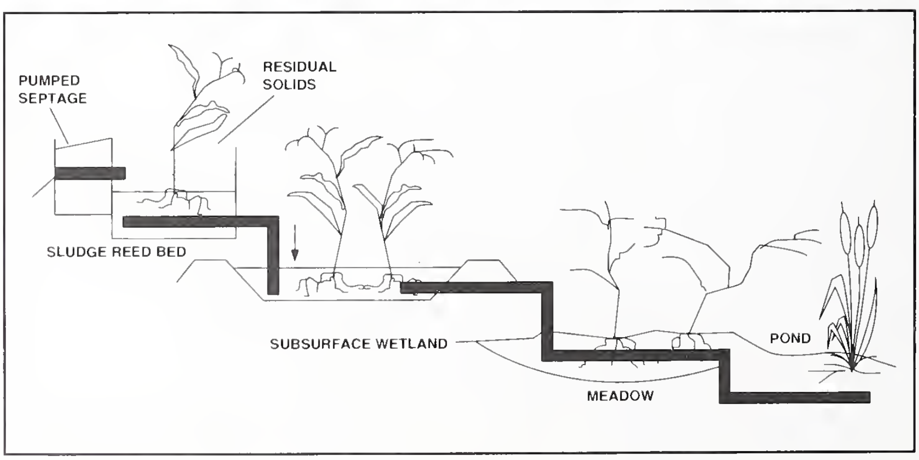

ET
Evaporation
18" —24"
Sand
Liner
Sand
Evaporation
18" —24"
ETA
Absorption




PUMPED
SEPTAGE
RESIDUAL
SOLIDS
SLUDGE REED BED
SUBSURFACE WETLAND
POND
MEADOW